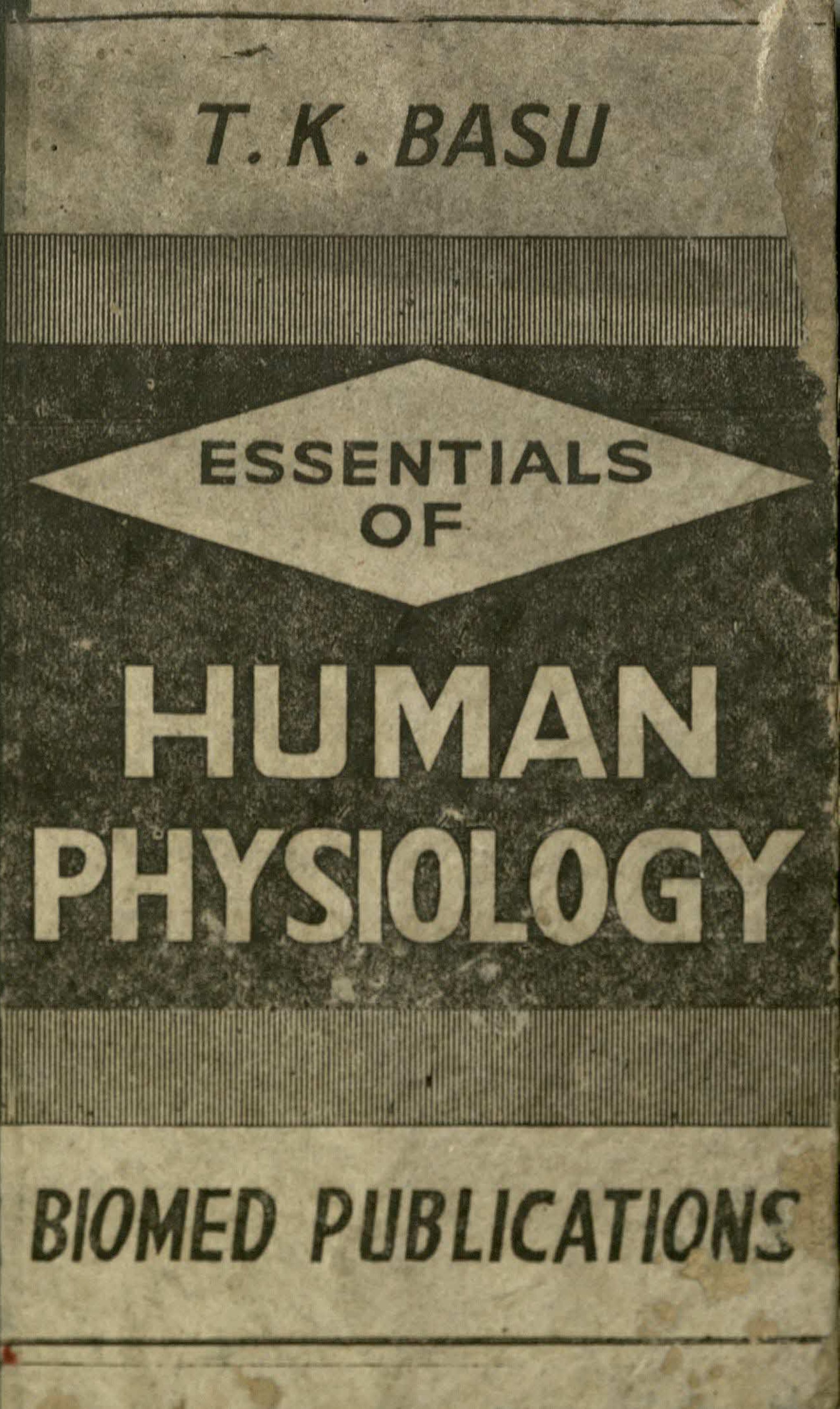

T. K. BASU

ESSENTIALS OF HUMAN PHYSIOLOGY

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ESSENTIALS OF
HUMAN PHYSIOLOGY

[*For Medical & B. Sc. Students*]

By

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13/1, Bankim Chatterjee Street, Cal-12.

DAS GUPTA & CO.
54-3, College Street, Cal-12

Published by ; Radhakamal, 3/1, Kartic Bose Lane, Cal-6.
Printed by : M. Pan, Nobin Saraswati Press, 17, Bhim Ghose Lane.
Calcutta-6

Complete Volume :
Price : Rs. 45·00

Volume One :
Price : Rs. 28·00

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PREFACE TO THE LATEST EDITION

The needs of publishing this book for the recent time speaks for its purposiveness for the students. I consider, therefore, my labour successful. In the persent edition, I have incorporated many new questions with their answers, a number of figures and short notes on individual chapters to meet the needs of the students. The revisions and new additions have been designed. I hope, the students will find this book as a helpful guide to their preparations during their examinations. Inspite of my best efforts, mistakes have crept in, for which I feel really sorry and owe an apology to our readers. Any suggestions from the teachers as well as students will be thankfully accepted and considered with every care and respect.

I would take the opportunity to acknowledge my debt of gratitude to my teacher and guide Dr. Bhola Nath Mitra, B. SC., M. B., D' Phil., Ex. Professor and Head of the Department of Physiology and Principal, R. G. Kar Medical College, for going through the book thoroughly and making valuable revisions. I am also thankful to Mr. M. Panja for their kind co-operation for printing this book.

T. K. Basu

CALCUTTA.
The 1st. July, 1975.

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CHAPTER
ONE

FUNDAMENTAL PHENOMENA OF LIFE

Introduction : The human body develops from a single initial cell which is formed by the fusion and fertilisation of the female germ cell i.e. the ovum by the male germ cell i.e. the spermatozoon. This initial cell is known as a zygote. The zygote grows and reproduces, forming millions of cells that develop into tissues. These tissues in turn develop into organs which form a new individual.

Q. 1. Define a Cell. Describe, in detail, the structure, properties and functions of a Typical Animal Cell.

The cells are the smallest units of living matter that can lead an independent existence and reproduce their own kind. So, an animal cell may be called as both the structural and functional unit of organisation of any multicellular organism. In a word, it may be defined as the basic unit of life. All the cells are bounded by a membrane, possess a nucleus which is the central controlling mechanism and semi-viscus cytoplasm that occupies the cell cavity.

Structure of a Typical Animal Cell. The structure of the cell is still the subject of a heated debate. The cells possess great variety of shapes, sizes and functions, However, the important essential features in a cell can be discussed : The cell surface is bounded by a *cell membrane* which is the living outermost boundary. In the centre of the cell, there is *nucleus* which is the controlling centre and partly capable of some synthesis and power supply. The cell cavity is occupied by *cytoplasm* which contains various sub-units like mitochondria, centrosome, golgi bodies, endoplasmic reticulum, vacuoles etc.

(1) **Cell Membrane or Plasma Membrane :** The cell membrane is living, elastic, rigid or not so, and capable of growth in an enlarging cell. It possesses a double layer and a double layer of lipid molecules remain within two layers of protein. The membrane is semi-permeable but the property of permeability is subjected to change depending upon some bio-physical conditions. It plays an important role in cellular nutrition and metabolism.

(2) **Nucleus :** It is the executive controlling centre for all the cellular activities because in nucleus, chromosomes and genes are present which determine the characters and activities of cell. It plays a role in protein and carbohydrate metabolism and is of vital importance to cell division and heredity. So, it is concerned with the control of constructive and functional activities of the

cell. The nucleus is usually spherical or oval in shape and lies in the centre of the cytoplasm. A non-dividing nucleus consists of a nuclear membrane, nucleoplasm, chromatin thread and nucleolus.

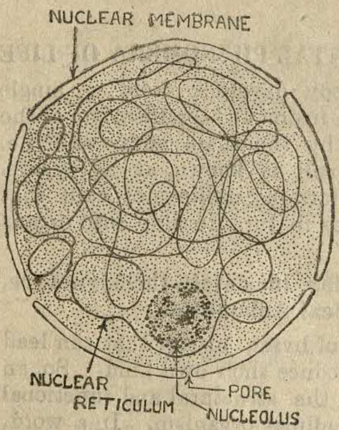


Fig. 1. (a) Mophology of a nucleus.

Each nucleus is enclosed by a nuclear membrane which is a double layer of proteins and lipids. There are one or more denser rounded bodies called nucleoli. The nucleus is made up of Ribose nucleic acid (RNA) and proteins. It is concerned with manufacture of proteins and also connected with the genetic information. The chromatin thread is the hereditary material of a cell. It possesses histone type of basic protein, another complex protein, Deoxy ribose nucleic acid (DNA) and Ribose nucleic acid (RNA). DNA is mainly concerned with heredity and is composed of several nucleotides having a nitrogenous base, a pentose sugar and phosphoric acid.

(3) **Mitochondria** : The mitochondria or chondriosome is mainly concerned with the cellular energy. It is 0·2 to 0·3 μ in size and spherical or rod-like in shape. These are present in all the living cells except in Red blood cells of human blood. The mitochondria is composed of protein, fat phospholipid, a small amount of ribonucleic acid, numerous essential enzymes including cytochrome, succinoxidase and various phosphatases as well as enzymes involved in the tricarboxylic acid cycle. Mitochondria are believed to play an important role in cellular mechanism of oxygen, carbohydrate, fatty acids and aminoacids.

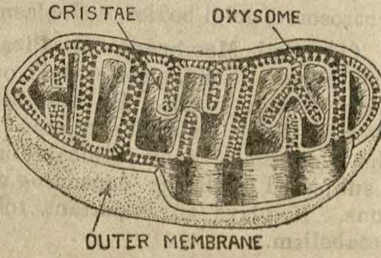


Fig. 1. (b) Mitochondria.

(4) **Golgi Complex** : The golgi complex or lipochondria consists of membranous lipoprotein structure containing RNA and alkaline phosphatase of with varieties of shapes and dimensions. The golgi complex is rich in lipid material and assists in the seggregation of materials within the cell. It acts as an

intracellular pump that regulates the movement of fluids in the cell and expulsion of secretory products from the cell. It is chiefly concerned in cell metabolism and probably has some relation with cell division.

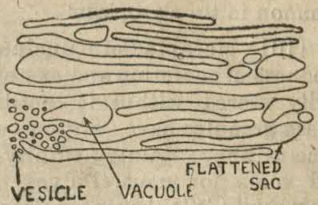


Fig. 1. (c) Golgi bodies.

(5) **Vacuoles** : The vacuoles are the liquid portions of the cell termed enclosed by a membrane the *tonoplast*. They contain water soluble substances like sugars etc. except the contractile vacuoles of Protozoa which eject waste products outside and the food vacuoles of unicellular animals. It is undoubtedly serve to transport substances into and out of the cell after performing the process of digestion and assimilation.

(6) **Endoplasmic Reticulum or Ergastoplasm** : The semi-viscus part of cytoplasm is now known to possess some compartments of membranes arranged regularly. It is derived from the nuclear membrane. This is called endoplasmic reticulum and contains very small many RNA-rich particles. It has been suggested that mitochondria may have a significant role in ergastoplasm formation.

(7) **Ribosomes** : Ribosomes or Microsomes or Claude's particles are the RNA-rich particles in the endoplasmic reticulum which are mainly concerned with protein synthesis of some steriods and may be involved in lipid metabolism. The microsomes are fragments of ergastoplasm. The biochemical study of microsomes discloses that they are composed of lipid, mostly phospholipid, ribonucleic acid and protein.

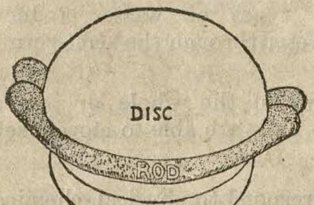


Fig. 1(d) Ribosome.

(8) **Centrosome** : Adjacent to the nuclear membrane the centrosome is a tiny cytoplasmic organelle that remainsas l radiating structures. The centrosomes are provided with astra rays and a central body or centriole. They seem to have a function in organising fibrillar material and mainly determine the polarity of a cell. The centrosome is absent in a nerve cell and so it losts its power of multiplicity.

(9) **Cytoplasmic Inclusions** : Besides the above mentioned structures, cytoplasm will often include reserve foods like

carbohydrates, proteins and fats. The pigments are also common in the cytoplasm.

(10) **Metaplasmic Inclusions :** It consists of granules and products of secretion and exeretion of the cell which are temporarily stored within it until they are eliminated by excretion. These granules have varying staining reactions, i.e. granules of some cell have staining affinity for acid dyes, some for basic dyes and some for neutral dyes. (i) The *Oxyphil* or *Acidophil* or *Eosinophil Cells* having staining affinity for acid or protoplasmic dyes. (ii) The *Basophil Cells* having staining affinity for basic or nuclear stain. (iii) The *Neutrophil Cells* having affinity for neither acid nor basic stains. (iv) The *Amphophil Cells* having equal affinity for both basic and acid dyes.

Properties and Functions of an Animal Cell : The cells exhibit the following properties and functions that are common to living things.

(1) **Metabolism** : It takes place in the living cells and helps to produce heat and energy, to build up and repair protoplasm and to produce secretions or enzymes.

(2) **Respiration** : Each cell requires oxygen for the process of metabolism. The utilisation of oxygen and production of carbondioxide serve cellular respiration.

(3) **Growth** : Cells have the ability to grow until they are mature and ready to reproduce.

(4) **Excretion** : The different types of waste products produced during metabolism are excreted through the semi-permeable cell membrane.

(5) **Movement** : The movement of the whole or part of a cell may occur. The white blood cells are able to move freely in the circulating blood.

(6) **Irritability** : The cell can respond to physical, chemical or thermal stimulus. A muscle fibre contracts when stimulated by a nerve impulse.

(7) **Reproduction** : It takes place when the process of growth of a cell is completed.

Q. 2. What is cell division ? How many types of cell divisions are there ?

At the very initial stage i.e. just after fertilisation, every organism is unicellular. After definite morphogenesis and histogenesis, the individual obtains its characteristic features. So, development from the unicellular initial stage to a multicellular complicated structure, the cells are to divide. The process resulting in multiplication of cell number is called cell-division. The cellular reproduction takes place through divisions of cell in which one mother cell divides into two daughter cells, each of which again divides into two, and so on multiplication goes on until full growth is obtained.

Types of Cell-Division : The cell-divisions are primarily of two types namely, Mitosis or Somatic cell-division and Meiosis or Germinal cell-division or Heterotypical mitosis.

(a) **Mitosis :** It concerns with the growth of the soma or body. In other words, division of body cell is called mitosis. In such a process, the daughter cells are identical regarding chromosome number and genetic characters.

(b) **Meiosis :** It is followed by gamete formation in animal kingdom. In gamete, the chromosome number should be half of that in body cells, so that after gametic union again the normal chromosome number of the body cell is restored. Meiosis is such a process which takes place in germinal cells and essentially concerns with the reduction in chromosome number. So it is also called reduction cell division.

(c) **Amitosis :** When constriction takes place on the nucleus which gradually increases and ultimately cleaved into two daughter nuclei mostly of unequal size, viz., some bacteria etc.

(d) **Free Cell Division :** Here the nucleus divides into two by mitosis. Each daughter nuclei undergoes mitotic division repeatedly and a large number of nuclei are formed which remain embedded in the cytoplasm. Then each nuclei is surrounded by some cytoplasm and ultimately secrete cell wall and produce many cells viz., in lower plant cells etc.

Q. 3. What is Mitosis ? Describe the different stages of Mitotic Cell Division ?

The usual behaviour of a cell during the period of growth when two cells form out of one, is called *Mitosis*. It is a dynamic mechanical process, a matter of push and pull, stress and strain.

The nucleus which is just going to divide i.e. at *interphase* shows some promient feautures. The size of the nucleus is large and nucleic acids and protein are synthesised as the preparatory step of division. The chromosomes are indistinguishable from one another.

Stages of Cell Division : The entire process of mitosis can be conveniently separated into four distinct phases namely prophase, metaphase, anaphase and telophase.

(a) **Prophase or Preparatory Stage :** The chromosomes are distinct thread-like and by longitudinal splitting they show two identical halves called chromatids. Dehydration and shortening of each chromosome occur. The nucleoli and nuclear membrane are present in this stage. The radiating structures near the nuclear membrane is called centrosome with astral rays in radiating manner. During prophase or even before, the centrosome divides into two and each half migrates, so that they lie opposite to each other. The position of centrioles determine the position of two poles of the cell body.

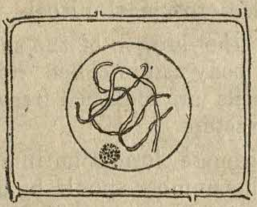


Fig. 2(a) Prophase.

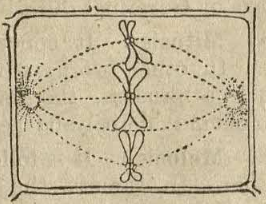


Fig. 2(b) Metaphase.

(b) **Metaphase or Attachment Stage** : The nuclear membrane and the nucleolus disappear with the appearance of the spindle in longitudinal direction between two poles. The spindles are long-chain protein molecules and they are attached into the chromosome by the centromeres.

(c) **Anaphase or Separation Stage** : The anaphase follows metaphase in the divisional cycle. The two chromatids of each chromosome starts separating from one another and migrating to the two poles. When the two sets of the chromosome reach the two poles, anaphase terminates.

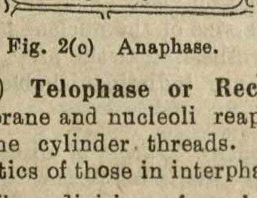


Fig. 2(c) Anaphase.

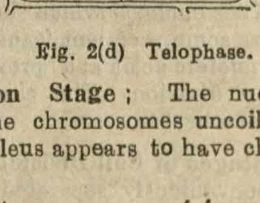


Fig. 2(d) Telophase.

(d) **Telophase or Reconstruction Stage** ; The nuclear membrane and nucleoli reappear. The chromosomes uncoil and become cylinder threads. The nucleus appears to have characteristics of those in interphase.

When division of nucleus complete, a process of furrowing starts near the equator and thus the cell is cleaved into two.

Significance of Mitosis : The chromosomes are the most important participants in the process of mitotic cell division. It has been shown that the chromosomes are the vehicles by which the hereditary particles are handed down from parent to offspring. The chromosomes are often composed of beaded structures known as chromomeres. The constancy of the chomosome being longitudinally differentiated. This differentiation shows the constant linear arrangement of genes. The exact reproduction of chromosomes into chromatids makes the daughter cell to have quantitatively and qualitatively the same genetic constituents of the original cells. In this way, the constancy of species is maintained serving the perpetuation of its own race.

Q 4. What is Meiosis ? Describe the different stages of Meiotic cell division.

Meiosis is the occurrence of two divisions of nucleus accompanied by one division of chromosome. It takes place only in the germ cell or gonad by which four daughter cells are produced from single mother cell bearing the half number of chromosomes. The special process of nuclear division which reduces the normal number of chromosomes to one half is called *Meiosis.*

Stages of Cell Division : Meiosis is a special kind of cell division and is regarded as an antithesis of fertilization because it reduces the chromosome number to half of the mother cell Meiosis involves two divisional cycles viz, first division of meiosis and second division of meiosis.

I. **First Meiotic Division** : The different stages of division can be conveniently distinguished as prophase, metaphase, anaphase and telophase of which the prophase stage is prolonged and genetically most significant.

(A) **Prophase I** : The prolonged prophase stage is again sub-divided into five sub-stages viz, Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

(*a*) In *Leptotene*, the nucleus enlarges and the chromosomes appear as single thread. The chromosomes appear in diploid number and so each type of chromosome is present in double number such an identical pair of chromosome is called homologous pair.

(*b*) In *Zygotene*, the homologous chromosomes pair with each other due to force of attraction between them. This pairing is called *synapsis*. So, at this stage the chromosomes remain in pair and the number of pairs or bivalents correspond with the haploid number of chromosomes. The coiling of the chromosomes still continues during these sub-stages and as a result the chromosomes become shorter and thicker as they increase in diameter due to their continuous coiling.

(*c*) In *Pachytene*, the chromosomes have shortened and thickened and more clearly distinguishable. At this stage, each chromosome divides longitudinally. Thus each chromosome forms two chromatids and a bivalent now appears to be a tetrad of four chromatids and the division enters into the next stage.

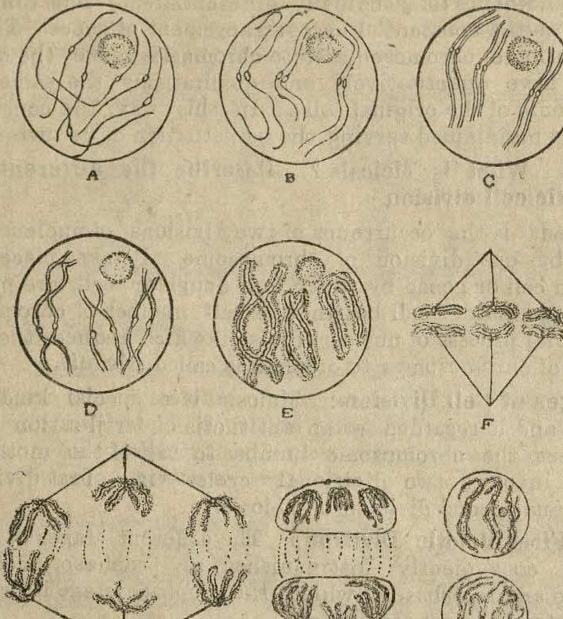


Fig. 3. Diagrammatic representation oi different stages of Meiosis.

(*d*) In *Diplotene*, the homologous chromosomes separate but each chromosome now consists of two threads or chromatids. At this stage, due to repulsion, the two pairs of chromatids are clearly visible. The two pairs remain attached at certain points which are called *chiasmata.*

(*e*) In *Diakinesis*, the chromosomes are more contracted and the number of chiasmata is reduced.

In all these stages of prophase, nuclear membrane and nucleolus are present.

(*B*) **Metaphase** I : In Metaphase, the nuclear membrane and nucleolus disappear and the spindle appears which is attached with the centromere. The ceromosomes are arranged in equatorial plane.

(C) **Anaphase I** : The chromosomes, each having two threads, start separating into two and move towards the two poles. So each pole receives chromosome in haploid number but as double thread structure.

(*D*) **Telophase** I : The nucleus is formed again and the cytoplasm is divided into two halves.

II. **Second Meiotic Division** : This division is known as *meiotic-mitosis* division. After the first divisional cycle of meiosis a short or long interphase is present which is even may be absent. Next a second divisional cycle starts which is called Equational division of the cell.

(A) **Prophase II** : A second prophase is present only in those cases where interphases are prolonged. If the interphases is very short or absent, the characteristics of second prophase are similar to that of first telophase.

(*B*) **Metaphase II** : The nuclear membrane disappears and spindle appear to get attached with the centromere of the chromosome. Each chromosome is now a double thread structure and the chromosomes are in haploid number.

(C) **Anaphase II** : The chromosomes start to separate towards the two poles each having a single thread.

(*D*) **Telophase II** The nuclei are reorganised and each contains haploid number of chromosomes in single thread.

Thus the chromosome number is halved and four daughter nuclei are produced from single mother nucleus.

Significance of Meiosis : Meiosis should be considered as a profound modification of mitosis by an alternation of time relationship at which the chromosomes pair and divide longitudinally. The meiosis or reduction division always occur in germ cells. It is one of the nature's technique by means of which she keeps the chromosome balance, when fertilization of the male and female nuclei takes place. In the long complicated process of meiosis, the diploid number becomes reduced to haploid.

Q. 5. What are the salient distinguishing features between Mitosis and Meiosis.

In cell division two facts are operative such as unsplit chromosomes always show a tendency of pairing and as soon as the chromosomes split, repulsion starts between the two paired homologous chromosomes.

The two types of cell-divisions viz , Mitosis and Meiosis differ essentially in the fact that mitosis occur in the body cell where the chromosome number remain same in the daughter nucleus, but meiosis takes place in germ cell during gametogenesis where the chromosome number is reduced. In fact the chromosomes divides in both the types of divisions but they are distributed in two nuclei in mitosis and in four nuclei in meiosis. So, in mitosis the chromosome number in the daughter nuclei remain same and that in meiosis is halved. In mitosis, the chromosomes divide during interphase but in meiosis during pachytene stage of Prophase. The chief distinguishing features are the following in a tabular form below :

Mitosis	**Meiosis**
1. Mitosis involves only one nuclear division which is involved with the duplication of the chromosome.	1. Meiosis is characterised by two nuclear division where the chromosomes are duplicated only one.
2. Mitosis occurs in the somatic cells of the organisms.	2. Meiosis occurs in the reproductive cells of the sexually reproducing organisms.
3. Before the onset of division the "resting stage" of nucleus is long.	3. Resting stage of the nucleus before division is short.
4. The main purpose of the mitosis is to increase the number of somatic cells in the body.	4. Meiotic division is of great significance in the sexually reproducing organisms in maintaining the chromosomes number constant.
5. The process of synthesis of deoxyribonucleic acid (DNA) takes place in the interphase.	5. The process of DNA synthesis proceeds upto Prophase I.
6. Prophase is of short duration.	6. Prophase is prolonged and divided into five sub-stages viz , Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Mitosis	Meiosis
7. The Prophase chromosome is a double thread structure because the chromosome divides longitudinally in interphase.	7. The Leptotene (Prophase I) chromosomes are single thread because they divide later in Pachytene.
8. There is no pairing between homologous chromosomes.	8. The homologous chromosomes pair during Zygotene.
9. Chromomeres are not prominent in chromosomes.	9. Chromomeres are prominent in chromosomes.
10. There is on segmental exchange between the homologous chromosomes. The chiasma formation and crossing over do not occur.	10. In Pachytene, the paired chromosome split longitudinally and chiasma formation and crossing over follow. Segmental exchange between two chromatids takes place and thus the 4 threads of the 2 chromosomes become different genetically.
11. In Metaphase, the chromosomes are arranged themselves in the equatorial plane and the spindle fibre attach to the centromeric position of each chromosome.	11. In Metaphase I, the chromosomes remain in equitorial plane and the chromomeres get attached with the spindle fibre.
12. In Anaphase, the chromosomes separate towards the two poles and each separating chromosomes possesses two identical thread.	12. In Anaphase I, the chromosomes start separation towards the two poles and each chromosome is double thread but the two thread are genetically different.
13. As there is a separation of the sister chromatids which move towards opposite poles, the somatic number of '$2n$' is maintained.	13. As there is separation of the entire chromosome and not of chromatids, the number of chromosomes moving to each pole is half of that present formerly on the equatorial region of the spindle. Thus the chromosome number is reduced from '$2n$' to 'n'.

Mitosis	Meiosis
14. In Telophase, two daughter nuclei are reorganised each having chromosomes equal in number to that in original nucleus.	14 In Telophase I, two daughter nuclei reorganised each having chromosomes equal to half the number of those in original nucleus.
15. One divisional cycle is present and there is no second division	15. Two divisional cycle are present. In Metaphase II, the chromosomes are arranged in equatorial plane and in Anaphase II, they seperate to two poles. In Telophase II, daughter nuclei are reorganised.
16. The chromosomes in the daughter nuclei possess single thread in some number to that in mother nucleus.	16. The chromosomes in the daughter nuclei possess single thread in reduced number.
17. At the end of mitosis, the number of daughter nuclei is two and identical qualitatively.	17. At the end of meiosis, the product of division is four nuclei and the daughter nuclei are not identical qualitatively.
18. The products are genetically same.	18. The products are genetically different.
19. Not related to evolution.	19. A basis of evolution by which recombination of characters takes place and better characters are asse-
20, Not related to the cycle of alternation of generation.	20. Required to maintain alterternation of generation. So, it may be antithesis of fertilization.

Q. 6. What is Tissue ? How many types of tissues are there in the body ? Describe the structure and functions of Epithelial tissue.

A tissue is a collection or aggregation or a group of similar types of cells being of characteristic size, form and arrangement, performing similar type of functions having a common origin but they are differentiated both structurally and physiologically. There are four major types of tissues. They are Epithelial or

Covering tissue, Connective or Supporting tissue including vascular tissue or blood and lymphoid tssue or lymph, Muscular or Contractile tissue and Nervous or Sensory tissue.

Epithelial Tissue: It covers all free surfaces either externally or internally and makes them smooth and regular. It is found internally for the investment of all the mucous membrane of the gut or the free surfaces of the skin as epidermis.

General Characteristics: (1) It forms an insulating material by which it covers all the free surfaces of the body and forms lining and limiting membranes of the gut. (2) The cells remain closely packed together, arranged in sheets with a minimum amount of intercellular cement substances known as mucoprotein. (3) All epithelial cells are get up generally on a delicate structureless fibrillar basement membrane. The cementing substance is a mucoprotein containing hyaluronic acid and calcium salts. (4) One surface of epithelium is always free and other resting. (5) The epithelial cells are frequently secretory and the secretory part of most glands is made up of epithelium.

Classification:

I. **Structurally**: According to the presence of a number of cells arrangement in layers, the epithelial tissue can be classified as follows :

(A) *Simple Epithelium* : It consists of single layer of cells. Depending on the nature of the cells, the simple epithelium is further sub-divided into pavement, colomnar, glandular, cubical and ciliated.

(B) *Compound Epithelium* : It consists of several layers of cells. It is sub-divided into transitional, stratified squamous cornified and stratified squamous non-cornified.

II. **Functionally**; According to function, the epithetial tissue can be divided into following ;

(a) *Absorptive and diffusive* : The columnar and pavement epithetial tissues are concerned in the process of absorption and in diffusion of gases and liquids.

(b) *Secretory* : The glandular and cubical epithelial tissues are concerned in the process of different types of secretions.

(c) *Protective* : The transitional, stratified squamous and columar ciliated epithelial tissues serve as the purpose of protection.

(d) *Sensory* : The epithelium associated with sensory end organs subserve sensory functions.

III. **Developmentally** : The epithelial tissues are developed from all the primitive germinal layers such as ectoderm, entoderm and mesderm and they are as follows :

(a) *Ectodermal Origin* : The epithelium of the skin and its appendages, lower part of anal canal, buccal cavity, labyrinth of the internal ear, eye and sensoy end-organs are ectodermal in origin.

(b) *Entodermal Origin* : The epithelium of the alimentary tract together with digestive glands with the exception of the buccal cavity and the lower part of the anal canal, respiratory system, biliary passages, pharyngo-tympanic tube and middle ear are endodernal in origin.

(c) *Mesodermal Origin* : The epithelium of the urinary and genital systems are mesodermal in origin.

Description of Individual Epithelial Tissue :

I. **Pavement Epithelium** :

(a) *Distribution* : It is found in alveoli of lungs, chorionic villi of placenta, Rete testis, Bowman's capsule and decending limb of Henley's loop, excretory ducts of pancreas, inner lining membrane of heart, back of cornea and inner surface of tympanic membrane.

(b) *Structures* : (1) It is made up of single layer of flattened scale-like cells of varying shape.

(2) They are closely fitted together to present a mosaic appearance.

(3) It is placed on a thin basement membrane.

(4) The central nucleus represents a superficial bulging due to thinness of the cells.

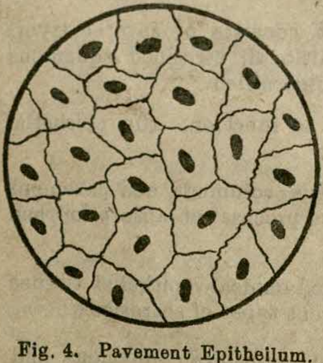


Fig. 4. Pavement Epitheilum.

(c) *Functions* : (1) It helps for easy passage of liquids and gases through it.

(2) It serves the function of protection.

(3) It has got a dialysing or filtering function.

II. Columnar Epithelium :

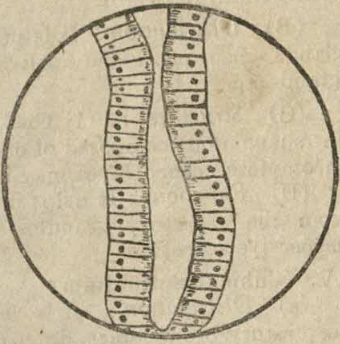


Fig. 5. Columnar Epithelium.

(a) *Distribution* : It is found in the mucous membrane of the gastro-intestinal tract from stomach to the upper part of the anal canal, gall bladder and the biliary passages.

(b) *Structures* : (1) It is made up of single layer of tall column-like or pillar-like cells which are closely packed together and the intercellular space is negligible.

(2) The elongated nucleus is found to be situated nearer the base of the cell. The basal knobs are believed to represent the fragmented centriole of the cell.

(c) *Functions* : (1) It helps in the process of absorption, concerns in the process of diffusion of gases and liquids. (2) It helps in the process of secretion of different types of digestive juices from the digestive glands.

III. Glandular Epithelium :

(A) *Classification* : Glands may be classified according to their structure, mode of distribution of their secretion, behaviour of the gland during secretion and according to their developments as follows :

(a) **According to structure**, the glands are simple tubular, branched tubular, coiled tubular, simple saccular, simple branched saccular. compound tubular gland, compound saccular or alveolar gland and compound tubulo-saccular or tubulo-racemose gland.

(b) **According to mode of distribution of the secretion,** the glands are Exocrine glands such as Salivary glands, Intestinal glands etc., Endocrine glands such as Pituitary, Thyroid, Parathyroid, Suprarenal etc. and mixed glands having both internal and external secretions such as Pancreas, Testes and Ovary.

(c) **According to changes in the gland cells during secretion,** the glands are Eccrine glands, Apocrine glands such as sweat glands, goblet cells, mammary glands etc. and Holocrine glands such as sebaceous glands.

(d) **According to development,** glands may be classified into ectodermal such as mammary glands, sweat glands etc. entodermal such as glands associated with digestive and respiratory tracts and kidneys and portions of testis and ovary are mesodermal in origin.

(B) *Distribution* : It is present in the mammary gland, sweat gland, sebaceous gland, salivary gland, intestinal gland, thyroid gland etc.

(C) *Structures* ; (1) They are generally cubical or polyhedral in shape and composed of one layer only. (2) Sometimes an incomplete second layer may be seen.

(D) *Functions* : It helps in the manufacture of new substances from the secretory granules and passing them out into their respective secretions.

IV. Cubical Epithelium :

(a) *Distribution* : It is found in secretory alveoli, terminal respiratory broncheoles, ducts of many excretory glands, follicles of the thyroid gland, germinal epithelial layer of the ovary and choroid plexus.

(b) *Structures* : (1) It is made up of a single layer of cubical cells having same dismensions on each side.

(2) The nucleus occupies the centre of each cell and the protoplasm is granular. (3) It is placed upon a basement membrane.

(c) *Functions* : (1) It forms a protective layer on the surface. (2) It helps in the function of secretion of different juices.

V. Ciliated Epithelium :

(a) *Distribution* : It is found in the respiratory passages from nose to the terminal bronchiole except the vocal cord, paranasal sinuses, nasal part of pharynx, uterine tube, endometrium of uterus, pharyngo-tympanic tube, tympanic cavity, ependyma of the ventricles of the brain and the central canal of the spinal cord.

(b) *Structures* : (1) The cells are columnar in shape with hair-like processes that project from the free surface fo the cells.

(2) Just within the cell outline opposite the free surface each ciliary process is found to present a knob-like thickening known as the *basal knob of Engelmann*.

(3) The basal knobs are believed to represent the fragmented centriole of the cell.

(c) *Functions* : (1) It helps to maintain the flow of liquid in one direction.

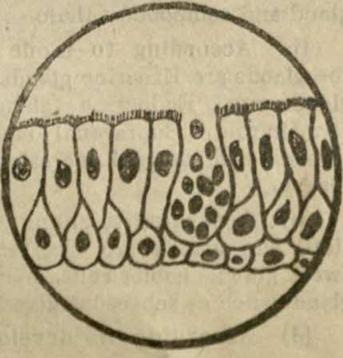


Fig. 6. Ciliated Epithelium,

(2) It carries ovum into the fallopian tube.

(3) It prevents to enter foreign particles and bacteria in the trachea.

VI. Stratified Squamous Cornified Epithelium :

(*a*) *Distribution* : It is found on the outer surface of the land-living animals such as in the epidermis of skin, hairs, nails. hoofs, horns, enamel of teeth etc.

(b) *Structures* : (1) The cells are arranged in several layers which become gradually flattened as they approach the surface.

(2) The surfrce cell layer gradually lose their protoplasmic character and cellular outline and become converted into a horny material known as "Keratin".

(c) *Functions* : It helps in the prevention of mechanical pressure, friction and injury.

VII. Stratified Squamous Non-cornified Epithelium :

(a) *Distribution* : It is found in the buccal cavity, tongue, lower part of pharnyx, oesophagus, lower part of anal canal, cornea, vocal cord, the vagina and the cervix of the uterus.

(b) *Structures* : (1) It is composed of the successive layers of squamous cells and the deepest cells from the basal cell layer which are columnar in nature. (2) The superficial layer is not keranatinised.

(c) *Functions* : (1) It helps in mechanical protection from coarse foods inside the mouth and the oesophagus. (2) It is provided on wet surfaces that are subjected to considerable wear and tear.

VIII. Transitional Epithelium :

(a) *Distribution* : The transitional epithelium is well adopted to lining tubes and hollow structures and thereby it constitutes the pelvis of the kidney, the ureter, the urinary bladder and the upper part of the urethra.

(b) *Structures* : (1) It consists of only three or four layers of cells. The surface layer of cells is slightly flattened the second layer of cells become pear shaped and its tapering end touches the basement membrane.

(2) The epithelium occupies an intermediate position between simple and stratified epithelium.

(c) *Functions* : (1) It serves the function of protection.

(2) It prevents reabsorption of the excretory material back to the system.

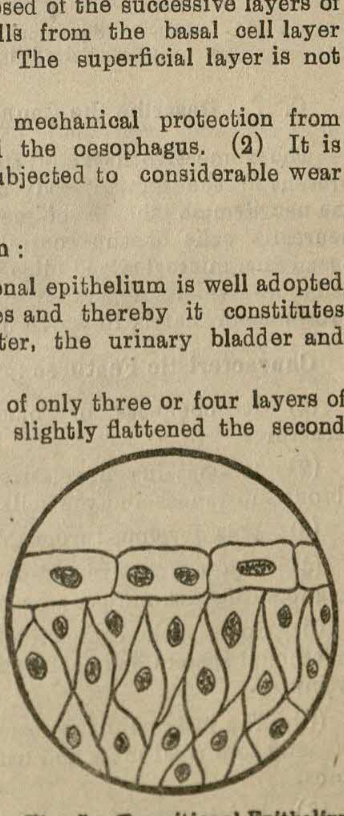


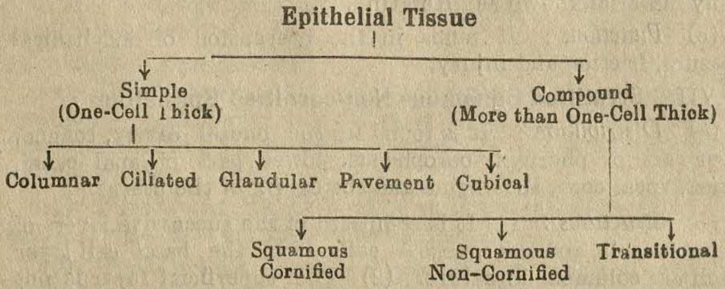
Fig. 7. Transitional Epithelium.

(3) It prevents indrawing of water from body tissues by the higher osmotic pressure of urine.

IX. **Stratified Columnar Epithelium :** It is rare in occurrence and found only in a few places, covering small areas like fornix of conjunctiva, some parts of pharynx, epiglottts, anal mucosa, cavernous part of the male urethra, etc.

X. **Stratified Columnar Ciliated Epithelium :** It is found in small areas like nasal surface of the soft palate, some portion of larynx. etc.

Summary :



Q. 7. Describe the Connective tissue in general.

The connective tissue is the most widely distributed tissue present in the human body and is mesodermal in origin except the neurilemma sheath of medullated nerves and some of the neuroglia cells of the central nervous system like astroytes, ependyma, microglea and oligodendroglea. The connective tissue cells are widely separated by large amount of intercellular substance or matrix in which fibres may or may not be present.

Characteristic Features :

(1) It connects or binds together functionally active structures.

(2) It contains a relatively large amount of intercellular fibrous substances and the cells being reduced to a minimum.

(3) It is developed from the mosoderm.

(4) The connective tissue cells appear isolated from their neighbouring structures and combat with foreign toxins.

(5) Some of the connective tissue cells belong to Reticulo-endothelial system and replace tissues which have been destroyed by injury.

(6) The intercellular substance is prominent, varies from a soft jelly to a rigid mass and usually contains connective tissue fibres.

(7) It forms packing materials around the organs.

Components of Connective Tissue :

The main components of the connective tissue are the *Connective tissue cells* and the *Intercellular substances.*

I. **Connective Tissue Cells :** The cells that are found in the connective tissue can be grouped into *Local or Histogenous Cells* and *Migrared* or *Haematogenous Cells.*

(A) **Local or Histogenous Cells :** These type of cells include Fibroblasts, Histocytes, Fat Cell, Plasma Cells, Pigment Cells and Mesenchyme Cells.

(1) **Fibroblasts** (*Lamellar Cells*) : *Structures* : These cells are more numerous, usually flattened, roughly triangular in shape with pointed processes and often branched in the cornea. , The cytoplasm is usually clear except a few fat globules, *Functions :* (i) The fibrobroblasts are non-motile and are not phagocytic in nature. (ii) It produces white fibrous tissue under physiological and pathological conditions. (iii) It is responsible for the formation of ground substance. (iv) It takes part is great role in the replacement of fibrosis during repair of inflammation. (v) There is an increase in cytoplasmic ribonucleoprotein granules in fibroblasts following tissue injury.

(2) **Histocytes** (*Clasmatocytes*) : They form irregular type of connective tissue cells. They are also known as resting wandering cells, adventitial cells and clasmatocytes. *Structures* : They are large and irregular in outline containing round or pleomorphic basophilic granular cytoplasm and may contain pigments and debris and vacuoles. Its nucleus is kidney-shaped and stains darkly. It shows selective staining reaction to vital stains by which it can be isolated from the rest of the connective tissue eells. *Functions* : (i) They are truly phagocytic in nature by which they can engulf foreign bodies, cell debris, etc. (ii) They are usually non-motile and show amoeboid movements under certain stimulus.

(3) **Fat Cells** : These remain supported by a loose framework of areolar tissue. *Structures* : The fat cells are generally large, rounded, oval or polyhedral in shape containing a large globule of free fat which is surrounded by a thin layer of cytoplasm and the flattened nucleus are pushed out to one side. The fat cells are stained black by Osmic acid and also stained by Sudan III or Scharlach R. *Functions* : The fat cells containing free fat inside it, form the adipose or loose tissue.

(4) **Plasma Cells** : These cells are generally distributed in the sub-peritoneal tissue of the omentum and in the submucous tissue of the intestine. *Structures* : These are large oval cells with non-granular basophilic cytoplaslm and rounded or oval eccentric nucleus, the chromatins of which are like the

spokes of a wheel. *Functions* : (i) They are believed to be the degenerative product of ordinary lymphocyte. (ii) They help in the synthesis of γ-globulin.

(5) **Mast Cells** : These are large, round or oval connective tissue cell, usually found in close proximity to the blood vessels and are usually less numerous. *Structures* : They are round or polygonal in shape with granular cytoplasm that stains with basic dyes. The nucleus is round or oval and being stained pale. It has observed under electron microscope that little granular endoplasmic reticulum or free RNA are present inside that mast cell. *Functions* : (1) They are believed to produce an anticoagulant substance known as the *heparin*. (ii) These help to produce *histamine* in allergic conditions. (ii) They elaborate a vasoconsrictor substance known as serotonin.

(6) **Pigment Cells** : The pigment cells contain melanin pigment in its cytoplasm. *Distribution* : These are mostly found in the pigmented areas of the body such as the gums, areola of the nipple, external genitalia, iris and the pigmented areas of mid-brain and the hind-brain. *Structures* : They are small branched cells with pigment in their cytoplasm. The pigment granules generally remain collectedround the nucleus. *Functions* : (i) The posterior pituitary secretes melanophore-expanding hormone which helps in the redistribution of pigments in the body. (ii) The change of environment like light, moisture, etc, causes dispersal of the pigment granules out into the cytoplasm.

(7) **Mesenchyme Cells** : These are embryonic type of connective tissue cells which are generally seen in adult individuals. *Structures* : They are branched type of stellate cells with protoplasmic processes and become continuous with the similar processes of the adjacent cells. *Functions* : These cells form a cellular syncytium.

(B) **Migrated or Haematogenous Cells** : These are formed elements of blood such as red blood cells and white blood cells. Their number greatly increases in local inflammatory conditions.

II. **Intercellular Substances** : The following are the intercellular substances found in the connective tissue. The type of connective tissue is determined depending on the relative amount of these substances. The intercellular substances are : (1) Collagenous or white fibres. (2) Yellow elastic fibres. (3) Reticular fibres. (4) Gelatinuous ground substance.

Classification : The following are the different varieties of connective tissue that fall into three main groups :

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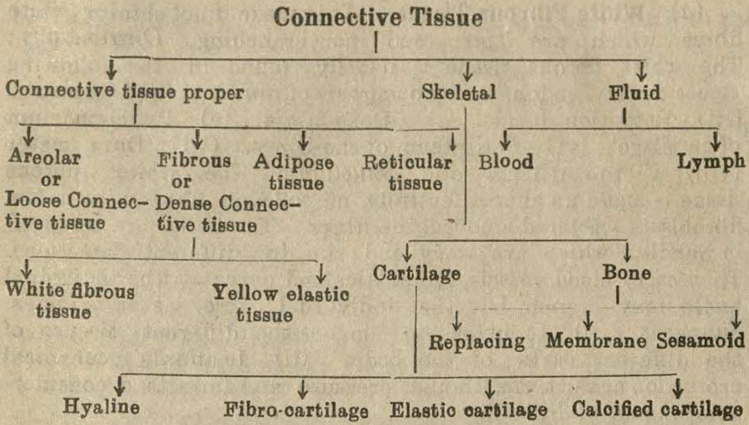

Description of Different Connective Tissues :

(A) **Connective Tissue Proper** : This tissue connects the different parts of the body together. It includes the following types : (i) Areolar or loose connective tissue, (ii) Fibrous or dense connective tissue, (iii) Adipose connective tissue, (iv) Reticular tissue, (v) Mucous connective tissue, etc.

(1) **Areolar Tissue** or **Loose Connective Tissue** : This is the simplest and the most widely distributed connective tissue found in the human body. *Distributions* : The areolar tissue is distributed (i) in the subcutaneous, sub-mucous and subserous tissues. (ii) between muscles, vessels and nerves. (iii) in the interior of organs binding the different parts. *Structures* : The areolar tissue consists of cells and fibres which are embedded in a homogenous ground substance. The *Cells* are the Fibroblasts, Histocytes, Fat Cells, Plasma Cells, Mast Cells, Pigment Cells and Mesenchyme Cells. The *fibres* are : (i) White or collagenous fibres which are wavy, unbranched and are arranged in bundles (ii) Yellow elastic fibres which are few in number, more slender, than the white and are not arranged in bundles but single fibres branch and join with one another to form a delicate network. *Functions* : (i) This tissue forms a sort of packing material around the orgrans. (ii) It plays a very important role in combating foreign toxins for it can react locally to produce inflammation, in which the number of cells and blood supply is increased and the macrophages in particular become phagocytes which can swallow germs of disease and destroy foreign bodies.

(2) **Fibrous or Dense Connective Tissue** : It is one of the variety of connective tissue which is composed mostly of fibres which may be either white collagenous fibres or yellow elastic fibres. The fibrous tissue may be divied into following varieties depending on the nature of the predominant fibres :

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(*a*) **White Fibrous Tissue :** It is made up of shining white fibres which are thin and non-branching. *Distributions* : The white fibrous tissue is usually found in the following places : (i) Tendon and aponeurosis of muscles, (ii) Ligaments. (iii) Retention bands, (iv) Deep fascia, . (v) Perichondrium of cartilage' (vi) Periosteum of the bones. (vii) Dura mater (viii) Fibro-cartilage, etc. *Structures* : The white fibrous tissue is made up almost entirely of collagen fibres with a few fibroblasts scattered amongst the fibres. The fibres are arranged in bundles which are wavy and run in different directions. They carry blood vessels, lymphatics and nerves. The individual budle may branch but the individual fibre never divides. *Functions* : (i) It helps to connect the different tissues of the different parts of the body. (ii) It affords mechanical protection aganist stretch and pressure and imparts a considerable amount of flexibility.

(*b*) **Yellow Elastic Tissue :** It is another variety of fibrous tissue, yellowish in colour, formed by the fibroblasts. *Distributions* : It is found in the following : (i) Ligamentum nuchae of the quadrupeds and the ligamnetum flavum of the vertebrates. (ii) Walls of the arteries and bronchi and in the larynx. (iii) Connective tissue framework of the lungs. (iv) Capsule of the spleen. (v) Vocal cords. . *Sturctures* : (i) It is thinner in cosistency. (iii) The fibres usually run singly but may form loose bundles in which the individual fibre can be identified. The bundles are usually straighter. (iii) The individual fibre freely branches and anastomoses with each other. (iv) When divided, the fibres curl up due to elastic recoil. (v) While transected, the fibres are seen to be angular with angles rounded off. (vi) Chemically, the elastic fibres contain an albuminoid substance known as elastin which can be digested by trypsin. *Functions* : (i) It has considerable strength, subserve the property of stretch and recoil and yet has remarkable elasticity and extensibility, (ii) By forming ligaments, it holds the connected parts firmly together and allows considerable latitude of movements. (iii) It prevents excessive dilatation in the blood vessels and by its elastic recoil serves to maintain general circulation and normal blood pressure. (iv) By its elastic recoil in the lungs, it maintains and adjusts the normal process of respiration.

(3) **Adipose Connective Tissue :** It is merely a modification of the ordinary areolar tissue in which the connective tissue cells or corpuscles are abundant and become very much enlarged through being filled with neutral fat, composed of a mixture of stearin, olein and palmatin. *Distributions* : The adipose tissue is widely distributed in all parts of the body such as in omentum, sub-cutaneous tissue, mesentry, perinephric region, subpericardial tissue, lactating mammary gland, etc. This tissue is absent in

the following places such as in (i) Subcutaneous tissue in the penis. (ii) Labia minora. (iii) Scrotum. (iv) Eye lids, (v) Cranial cavity and (vi) Lungs except at the hilum. *Structures* : The adipose tissue consists of fat cells containing free fat inside it. A fat cell consists of large, rounded or oval cell containing a large globule of free fat which is surrounded by a thin layer of cytoplasm and a nucleus that is displaced at the periphery. The fat cells may be stained by Sudan III or Scharlach *R* or Osmic acid. *Functions* : (i) It forms a pad on which the skin rests and often contributes to the beauty of form in a healthy individual. (ii) It prevents injury by surrounding the viscera and keeps them in position. (iii) It acts as a buffer action by which it protects the body from any external shock or injury. (iv) It acts as a cushion in the eye-socket. (v) It plays a good role in the regulation of body temperature. (vi) It represents stored energy which is supplied in emergency and starvation.

(4) **Mucous Connective Tissue** : This is a variety of connective tissue which is usually found in many parts of the body during development. *Distribution* : It is present as jelly-like material of the umbilical cord in foetal life and is not present in adult life. *Structures* : This type of connective tissue consists of star-shaped fibroblasts with anastomosing processes mucin-contraining soft ground substance and a few collagen fibres. *Function* : This tissue forms a jelly-like material known as Wharton's Jelly in the umbilical cord in growing foetus.

(5) **Reticular Tissue** : It is one of the connective tissue and is similar to the areolar tissue. It is found to form networks of fine connective tissue fibres known as reticular fibres which branch and anastomose freely. *Distributions* : It is usually found as a supporting networks in the lymph node, bone marrow, splenic pulp and in the liver. *Structures* : (i) It is thinner, freely branching and resists peptic digestion. (ii) It is selectively stained by silver oxide or carbonate solution and hence they are also known as argyrophil fibres. (ii) The interspaces are very small and are largely occupied by lymph and tissue fluid. *Functions* : (i) The lymphocytes are manufactured from the lymph node which serve as antibody formation and check bacterial infection. (ii) The reticular cells are manufactured from the bone marrow and the splenic pulp which anastomose with each other to form a protoplasmic syncytium.

(B) **Skeletal Tissue** : This tissue includes cartilage and bones which form the endoskelton of the vertebrate body. According to the difference in the number of cartilage cells and the nature of the ground substance present cartilage is divided into two classes—Hyaline cartilage and Fibro-cartilage.

(1) **Hyaline Cartilage** : Most of the bones in the foetus are preformed in hyaline cartilage. *Distributions* : After birth,

the persistence of hyaline cartilage is found in the following : (i) Articular cartilage—found in the articular end of the bones. (ii) Epiphyseal cartilage—between the epiphysis and the diaphysis of the growing long bones. (iii) Costal cartilage—at the anterior end of the ribs. (iv) Cartilages of the nose, trachea, bronchi and larynx except the epiglottis, cuneiform and corniculate cartilages. *Structures* : The hyaline cartilage consists of ensheathing perichodrium made up of fibrous tissue, encapsulated cartilage cells and homogeneous ground substance. The cartilage cells are large, rounded and are surrounded by capsule. The nucleus is small with one or more nuclei, the cytoplasm is usually clear with a few fat droplets, glycogen granules and occasionally some pigments. The cells are usually arranged in groups of two, four, etc. having a common capsule. Each group of cells arises from the multiplication of a single parent cartilage cell. The intercellular ground substance in the hyaline cartilage is homogeneous and is laid out in concentric rings and take deeper stain. The deeply stained portion around the cells is called the capsule. *Functions* : (i) It helps to maintain the ahape and rigidity of structure combined with certain amount of elasticity. (ii) It provides a resistant material for the attachment of the mucles and consequently have a considerable rigidity, (iii) This rigidity enables them to act as levers of great importance in the movements or limbs and their resistant properties enable them to give protection to delicate structures enclosed by them. (iv) It acts as a mechanical buffer as found in the intervertebral discs, articular menisci, etc. (v) It serves as a primary medium in which crtilaginous development of bone takes place. (vi) Due to its great elasticity and resistance to crushing, the cartilage relieves the bones of socks and serves to keep passages open and organs distended.

(2) **White Fibro-Cartilage** : It differs from the hyaline and elastic cartilage in that it has no perichondrium and its intercellular substance contains dense bundles of collagen fibres. *Distributions* : It is found in the interverebral disc, interarticular disc or menischi, symphysis pubis and at the attachment of some of the tendons and ligaments to the bones. *Structures* : The cells are large, usnally scanty and wide apart. They are arranged in groups and each group is surrounded by a clear rim of hyaline material. They are typical cartilage cells with capsules. *Functions* : This tissue may be regarded as a transitional type between hyaline cartilage and areolar tissue.

(3) **Yellow Elastic Cartilage** : It is fundamentally similar to hyaline cartilage possessing numerous yellow fibres which run through the matrix in all directions. *Distributions* : It is found in the external ear or pinna, externa auditory meatus, phayngo-

tympanic tube, epiglottis, at the end of the nose, cuneiform and corniculate cartilagee of the larynx. *Structures* : The yellow elastic cartilage consists of typical encapsulated cartilage cells and intercellular ground substance. The ground substance contains branching elastic fibres which form anastomosing network around the cells. The fibres nearer to the surface are continuous with the perichondrium. *Functions* : It owes its great flexibility to the presence of numerous yellow fibres.

(4) **Calcified Cartilage** : It differs from the hyaline type in having its matrix impregnated with lime salts. This variety occurs in the pubis of old frogs, in the suprascapula and at the head of the humerous and femur.

(5) **Bone** : It is the hardest connective tissue in which the ground substance of the matrix, which is composed of elastin, is impregnated with various inorganic salts of lime, namely, calcium phosphate, calcium carbonate, magnesium phosphate and calcium flouride.

(a) **Divisions of Skeleton** : The subdivisions of the skeletal system may be summarised as follows :

(i) *According to Location*, the skeleton may be divided into Exoskeleton and Endoskeleton.

(ii) *Developmentally*, the skeleton may be divided into Somatic skeleton and Visceral skeleton.

(iii) *Based on a stem with appendages*, the skeleton may be divided into Axial skeleton and Appendicular skeleton.

(b) **Classification of Bones** : The bones are altogether 206 in number in the human skeleton which may be classified as follows :

(i) *According to Development*, the bone is divided into Membrane bones, Cartilage bones and Membrano-cartilagenous bones.

(ii) *According to shape, size and consistency*, the bone is divided into Long bones Short bones, Flat bones, Irregular bones, Sesamoid bones, Pneumatic bones and Supernumerary or accessory bones.

(iii) *According to the density and hardness*, the bone is divided into Compact bones, Spongy or Cancellous bones and Diploic bones.

(iv) *According to microscopic structure*, the bone is divided into Lamellated bone, Haversian bone, Fibrous bone, Dentine and Cement.

(c) **Structures** : In human bones, there are great many longitudinally running *Haversian canals*, each of which contains an artery, a lymphatic vessel, a nerve and some bone cells or osteocytes. The Haversian canals connected to each other by transverse *Volkmann's cannals.* Each Haversian canal, with its group of surounding lamellae, forms the *Haversian system.* In between adjacent Harversian systems, there are *interstitial lamellae.* Surrounding the marrow there are *inner circumferential* or *inner contour lamellae* and immediately underneath the periosteum there are *outer circumferential* or *outer contour lamallae.*

(d) **Functions :** (i) It acts as a supporting framework upon which the body is built up. (ii) It serves as levers for muscles. (iii) It acts as a protective function by which it prevents any sorts of external injury to the body. (iv) It contains red bone marrow from which red blood cells are manufactured. (v) It is the store house of calcium and phosphorous.

(C) **Fluid Connective Tissue :** The fluid connective tissue comprises of blood and lymph.

(a) **Blood :** The blood is an actively living and circulating liquid connective tissue consists of a liquid portion known as plasma and the cellular portion known as Red blood cells, White blood cells and Platelets.

(b) **Lymph :** It is one of the type of liquid connective tissue which is manufactured from the lymph nodes with plentiful lymphocytes. It circulates within the lymphatic system of the body.

Q. 8. Describe the Classification (Development), Structure and Functions of Bone.

Bone is a specialised type of connective tissue, in which the ground substance is rendered rigid by impregnation with calcium salts. The basic material component is a hydroxyapatite—a calcium phosphate-calcium hydroxide complex.

Classification (Development) of Bone.

I. **Causes of Bone Formation :** There are several factors that may be involved in the process of bone formation are the following :

(1) The activity of a phosphatase in the region of the hypertrophic cartilage cells.

(2) The activity of alkaline phosphatase along with nucleic acid in the osteoblasts cytoplasm.

(3) Vitamin D is necessary for calcification. There will be overgrowth of improperly calcified osteoid tissue, as in rickets when Vitamin D is absent.

(4) The Parathyroid gland is concerned with calcium and phosphate ionic balance.

(5) The adenohypophysis of pituitary gland is concerned with bone formation.

(6) The nervous system acts probably through its control of supplying blood vessels.

II. **Laws of Ossification** : There are a number of laws upon which the ossification of bones are based. The laws of ossification are the following :

(1) Ossification may begin either from a membrane or from a cartilage.

(2) Ossification begins from a particular point known as centre of ossification and it spreads out in a radiating manner to different portions of the bone.

(3) Centre of ossification may be primary or secondary.

(4) Primary centres may be single or multiple and usually appear before birth.

(5) Secondary centres are usually multiple and appear after birth with the exception of the lower end of the femur.

(6) The multiple primary centres, all appear simultaneously.

(7) The multiple secondary centres appear at different dates of life.

(8) The epiphysis which begins to ossify first, unites with the diaphysis last and vice-versa.

(9) The centre of ossification for the epiphysis appears first in the growing end of the bone.

(10) The different centres of ossification of an epiphysis unite together first before union with the diaphysis.

III. **Process of Ossification** : The ossification is the process of gradual bone formation. The mesenchymal cells form the structural basis which may be either a membrane or a cartilage in which the ossification is to take place. There are two processes of ossification—Intramembranous and Endochondral or Intra-cartilaginous ossification.

(a) **Intramembranous Ossification** : The original matrix spreads out in the form of a membrane which becomes vascularised and strands of fibres appear in this medium forming *Osteogenic fibres*. The primitive connective tissue membrane becomes richly vascularised and become collected into bundles. They are enclosed in a calcareous ground substance formed by the deposition of calcium salts forming *centre of ossification*. The osteoblasts now appear and deposit bone in the shape of branching lamellae. In this way, ossification proceeds. Some of the osteoblasts become surrounded by bony deposit and form isolated bone cells in the lacunae. The bones of the face, cranial vault and the clavicles are ossified in this way.

(b) **Endochondral (Intra-cartilaginous) Ossification** : The ossification starts at about the centre of the *diaphysis*. It then proceeds and extends for the centre towards the epiphysis, when *secondary ossification centres* appear. The process in the epiphysis then extends both towards their end as well as towards the primary ossification centre. The layer of epiphyseal cartilage is packed in between the ossifying diaphysis and epiphysis. The epiphyseal cartilage is responsible for growth in length of the skeleton. Once the epiphyses have joined with the diaphyses, growth in length of the skeleton is impossible. It occurs usually at about the twenty-fifth year of life. All limb bones and those of the vertebral column are ossified in this mechanism. In this case, the mesenchymal cells at first differentiate into cartilage cells and cells forming the perichondrium and degeneration of the main mass of the cartilaginous model and the degenerated cartilaginous mass is replaced by bone by ossification.

These following stages have been recognised in endochondral or intra-cartilaginous ossification. They are as follows : (1) **Stages of Hypertrophy** : This occurs in the primary ossification centres and presents the following features : (i) The cartilage cells enlarge and the cytoplasm becomes rich in glycogen containing vacuoles and a degenerating nucleus. These cells arrange themselves in linear rows radiating from the centre, (ii) Irregular deposition of calcium salts takes place between the cells. (iii) The sub-periosteal osteoblasts form new bones underneath the periosteum. (2) **Stage of Irruption** : The sub-periosteal cells containing osteoblasts and osteoclasts become hyperactive and eat away a portion of the newly formed subperiosteal layer of bone. Through this eroded spot the sub-periosteal osteoblasts, osteoclasts, connective tissues and blood vessels stream down into the depth of the bone and invade the calcified matrix. The calcium deposits are freely absorbed by the multinucleated osteoclasts and hollow spaces are produced which are known as *primitive marrow spaces*. (3) **Stage of Ossification** : The osteoblasts then lay down osteoid tissue in a regular lamellated manner. Gradually when this formation taking place successively, some osteoblasts become imprisoned as bone cells or *osteocyte*. The marrow spaces in the centre coalesce and form the *medullary canal* and, simliarly *Haversian Systems* are developed. (4) **Stage of Epiphyseal cartilage formation** : It is done in case of long bones only which are associated with those bones which have epiphyses. The cells in the central zone of the mesenchymal condensation directly change into cartilage cells. These young proliferating cartilage cells give rise to the formation of the epiphyseal plate and the epiphysis.

Structure of Bone : The bone is a specialised variety of connective tissue consisting of following structures : (1) **Periosteum :** It is a vascular fibrocellular membrane consisting of two layers that covers the bone The outer membranous layer is made up of dense collagenous connective tissues with blood vessels, nerves and only few fibroblasts. The inner cellular layer is made up of elastic tissue and osteoblasts and osteoclasts cells. (2) **Haverian Canals :** These are longitudinal tunnels containing one or two blood vessels, lymphatics, nerves and there may be a few marrow cells. (3) **Haversian lamellae :** These are concentric circles of layers of deposited bones around each Haversian Canal. (4) **Lacunae :** In between the adjacent layers of Haversian lamellae, there are tiny spaces called *lacunae* which are also arranged in circles around the *Haversian Canal.* (5) **Canaliculi :** These are fine passages arise from these lacunae which contain the processes of the osteoblasts and penetrate the hard interstitial matrix.

Functions of Bone : (1) The periosteum is concerned with the nourishment of the bone by bringing to it blood vessels and nerves, give attachment to muscles and tendons checks excessive bony growth and helps regenerate new bone. (2) The bone protects the vital organs of the body like Heart, Lung, Kidney etc. (3) It forms the rigid skeleton of the body. (4) It acts as a store house of calcium and phosphorous. (5) The bone marrow is present within the bone and thereby it serves as a haemopoietic function. (6) It is one of the chief seat of Reticulo-Endothelial System.

Q. 9. Describe the structure and function of Muscular tissue.

The sign of movements done by the muscles help in the differentiation of animates form the inanimates. The muscular tissue in higher animals controls the movement of different parts of the body by the process of alternate contraction and relaxation and thereby contractility is the inherent property of all types of muscular tissue.

Characteristic Features :

(1) In muscular tissue, the muscule fibres are present which are arranged in bundles or fasciculi and the muscle fibres in each fasciculus run parallel to one another.

(2) An individual muscle fibre is surrounded by a delicate layer of loose areolar tissue known as 'endomysium'.

(3) A group of muscle fibre is arranged into a bundle to form individual muscular fasciculus which is surrounded by another denser layer of areolar membrane known as 'perimysium'.

(4) The muscular fasciculi are bounded and ensheathed together by a common areolar membrane known as 'perimysium' to from the individual muscle.

(5) The epimysium becomes thickened to intervene between two groups of muscles forming intermuscular septum.

Varieties of Muscular Tissue :

(a) **Structurally,** the muscular tissue can be divided into Striated, Non-striated or plain or smooth and Cardiac muscles.

(b) **Functionally** . it can be divided into Voluntary and Involuntary muscles.

(c) **Developmentally,** the muscular tissue can be divided into Myotomic or somatic and Splanchnotomic or visceral muscles.

I. Histological Structures of Striated or Somatic or Voluntary muscle.

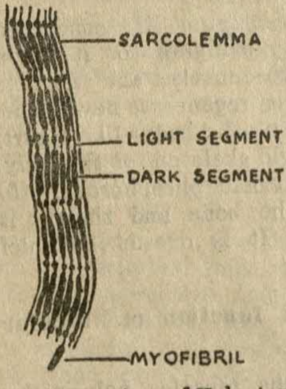


Fig. 8. Structure of Voluntary muscle fibre showing alternate white and dark segments.

Distribution : This muscle concerns with movements of the body controlled by will. These muscles are distributed in the skeletal area where they are attached such as, biceps muscle, triceps muscle etc.

Structures : (1) Each muscle fibre consists of an outer membranous covering known as *sarcolemma*, within which *sarcoplasm*, the protoplasmic mass is present.

(2) The sarcoplasm contains a number of fine, delicate fibrils known as myofibrils.

(3) The myofibrils are alternatively called *sarcostyles* and are divided into light and dark coloured segments or *sarcomeres*.

(4) Each dark segment is doubly refractile and appears dark by transmitted light and is known as *A-disc* or *Dobie's dots.*

(5) Each light segment is singly refractile and appears clear by transmitted light which is known as *I-Disc* or *J-Disc.*

(6) Each J-disc is crossed by another very thin *Z-Disc* or *Krause's membrane* which is continuous right accoss the fibre and at the periphery with the sarcolemma.

(7) Each dark coloured *A-Disc* may also be crossed by light coloured disc known as *Hensen's disc* which can be seen in expanded or relaxed state.

Functions : The voluntary muscle are made up of large muscle fibres which concerns with movements of the body controlled by will performing voluntary action.

II. Histological Structure of Unstriated or Involuntary or Visceral muscle.

Distributions : The involuntary muscles are widely distributed in the body. They are found in the walls of the hollow viscera, blood vessels, hollow ducts of the exocrine glands, in the sweat glands, within the fibrous capsule of the spleen and lymph glands, in the intrinsic ocular muscles such as in the iris and ciliary bodies, in the walls of the terminal bronchiole and in the muscles of Muller.

Structures : (1) The visceral muscle consists of elongated fusiform cells with a centrally placed single oval nucleus along with one or two nucleoli.

(2) The nucleus is surrounded by a small mass of cytoplasm known as *sarcoplasm*.

(3) The sarcoplasm contains delicate longitudinal myofibrillae, supposed to be the contractile elements of the cell and they do not possess any transverse striations.

(4) There is a sarcolemma and the cell wall is formed by a delicate membrane of reticular tissue.

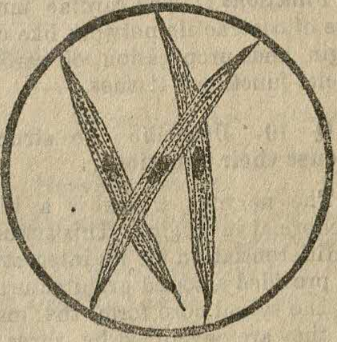


Fig. 9. Structure of Involuntary muscle fibre.

Functions : The involuntary muscle act independently without having any volitional control.

III. Histological Structure of Cardiac muscle.

Distribution : The cardiac muscles are the muscles of the walls of the heart.

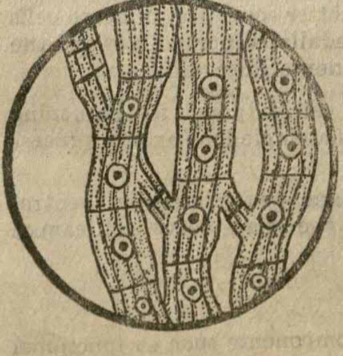


Fig. 10. Structure of Cardiac muscle.

Structures : (1) The cardiac muscles fibres consist of quadrangular forked cells with central nuclei and the branches of the adjacent muscles freely anastomose with cell to cell and branch to branch forming a contractile network known as cellular syncytium.

(2) The sarcolemma is ill-defined and intervening between the fibres is a very thin layer of loose connective tissue.

(3) The sarcoplasm is more granular and contains myo-

fibrillae towards the periphery of the cells whereas the nuclei are placed centrally either in rows or in close packing.

(4) Each of the muscle fibre is trasversely marked by darkly staining bands known as the *intercalated disc* which are not straight transverse marking concerned together in steps.

(5) The electorn microscopic structure shows that each myocardial fibre have got 300 to 700 myofibrils.

(6) The capillaries are seen to enter the myocardial fibre carrying blood to the sarcoplasm, nuclei and myofibrils. Large numbers of sarcosomes are seen scattered among the myofibrils and near the poles of the nuclei but never within the myofibrils.

Functions: The cardiac muscles though possess a special type of contractile network like cellular syncytium, help for the origin and propagation of cardiac impulse with the help of special junctional tissues.

Q. 10. Describe the structure of Nervous tissue and discuss their functions.

The nervous tissue is a highly specialised tissue which is ectodermal in origin. This tissue is incapable of further re-or de-differentiation for its integration into the body and so nature has provided a sound architecture for its protection. The brain and the spinal cord form the main bulk of the nervous tissue and they are enveloped by three meningeal layers from outside inwards known as duramater, arachnoidmater and piamater. Moreover the brain is externally covered by rigid bony cranial cavity and the spinal cord is covered by a long chain of bony vertebrae known as vertebral column.

Characteristic Features ;

(1) Macroscopically, the nervous tissue consists of grey and white matters.

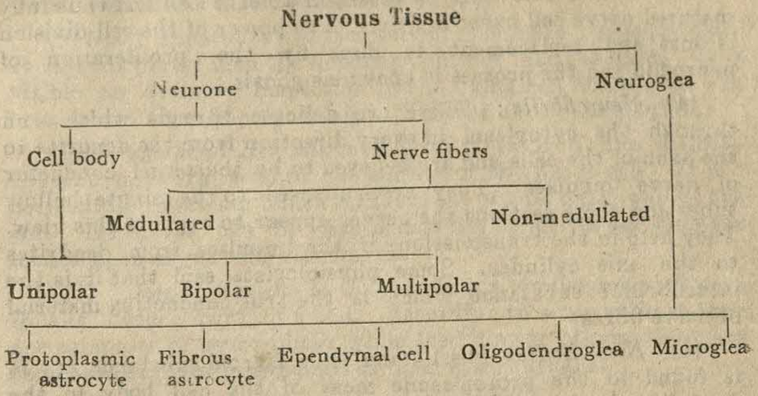
(2) Microscopically, the grey matter consists of nerve cells of varying shape and size and non-medullated nerve fibres and the white matter consists of medullated nerve fibre.

(3) Each nerve cell consists of a cell body and its branching processes of various patterns such as a single long axonic process and numerous short dendritic processes.

(4) Presence of Nissl's granules and neurofibrils but centrosome is absent in the nerve cell and therefore nerve cell cannot perform cell-division.

Classification of Nervous Tissue :

The nervous tissue has got two components such as functional component and supporting component. The functional component comprises the *Neurone* which is made up of nerve cell and the two processes—the *axon* or axis cylinder and the *dendrons* or dendrites. The supporting component is known as neuroglia which is mainly developed from ectoderm and partly developed from mesoderm.



(A) Functional Component of Nervous Tissue :

The functional component is made up of neurones. A neurone is the structural and functional unit of the central nervous system. Each neurone is made up of a nerve cell which consists of a cell body known as *Cyton*, and long and short processes known as the axon and the dendron respectively. The nerve cell receives impulses through its dendron and transmits the same impulse through its axon to other cells. The dendron carry its impulse towards the nerve cells but axons carry the impulse away from the nerve cells. The axon of one cell arborises round the dendrons or the cell body of another making an intercommunicating contact which is known as *Synapse*.

(a) **Nerve Cell Body :** (Fig. 11) The nerve cells vary in size and shape in different parts of the body. Their sizes and forms may be stellate, round, pyramidal, fusiform etc. According to the number of processes, the cell may be **Apolar** (no true axis cylinder) found in the cerebral cortex, inner nuclear layer of the retina etc., **Unipolar** (axon and dendrites arising from common stem forming a T-shaped junction) found in sympathetic ganglion etc., **Bipolar** (one axon and one dendrite) found in cochlear and vestibular ganglia, cells of the Clarke's column etc. or, **Multipolar** (one axon and many dendrons) found in the majority of the cells in the spinal cord like anterior horn cells and the cells of the sympathetic ganglia. The nerve cell contains central nucleus, mitochondria, golgi apparatus, pigments, Nissl granules. neurofibrils etc. in the cytoplosm.

(*1*) *Nucleus* : It is generally large, clear, spherical and often presenting an intracellular network of chromatin. It usually lies in the middle of the cell body and contains wellmarked nucleoli.

(2) *Nucleolus* : It is generally large and distinct, situated within the nucleus.

(3) *Centrosome :* It is absent in a nerve cell and thus fully matured nerve cell never multiply. The power of the cell-division is lost and replacement is done by the proliferation of neuroglia and the process is known as gliosis.

(4) *Neurofibrils* : These are delicate threads which run through the cytoplasm in every direction from the dendrite to the axon of the cells and are believed to be the actual conductor of nerve impulses. They are supposed to be minute hollow tubes and some sections the nerves appear to support this view. They help in the transmission of the impulses from dendrites to the axis cylinder. Some physiologists said that it is the interfibrillar substance which is the true conducting material of nerve-fibres.

(4) *Nissl Bodies* (Nissl granules or Tigroid substance *)* : It is found in the protoplasmic mass of the cell body in the dendrities in the sympathetic ganglionic cells and excepting the axon hillock from where the axis cylinder arises. They are spindle-shaped angular masses of bosophilic mrterial present in the cytoplasm. They vary greatly in their size and number in different cells and in the same cell under different conditions. They consist of chromatoplasm or chromatophilic material which is an iron containing nucleo-protein. It is composed of Ribo-Nucleoprotein or R. N. P, and organically combined Iron. It is also called kinetoplasm and it is believed to represent a store of nervous energy. These are bluish in colour and also known as Tigroid substance. Under certain conditions, the Nissl granules disintegrates and disappear which is known as *Chromatolyis*. During rest the granules reappear. It has been suggested that the Nissl granules act as a catalysing agent in increasing the metabolic activity of the cell and are intemately connected with the nutritional condition of the neurone. These granules are explained as accumulation of reserve material to be drawn upon for functional purposes. The Nissl granules are parallelly arranged membrane bound cavities contaimining cisternae. In dendrite, the granules are rod-shaped in motor neurone they are coarse whereas in sensory neurone, they are dust-like. Probably they release minute quantities of iron which acting as catalytic agent to increase metabolic activity of the cell and thereby help in the conduction of nerve impulses.

(5) *Cytoplasm :* The cytoplasm is characterised by the presence of basophil granules and neurofibrils which are easily seen by Cajal's method of staining.

(7) *Mitochondria* : It is scattered in the cytoplasm as small rodlets granules and is visible in the living state. There are phosholipid-protein inclusions which often appear in granules or filaments. It is believed that mitochondria secrete the enzymes which help in the metabolism of cell body.

(8) *Golgi Apparatus :* It is a network found in the cytoplasm. It extends partly into the dendrons but not into the axon. It is visible on ordinary inspection in the living cell bodies. It can be detected after impregnation with silver chromate solution.

(9) *Superficial Reticulum of Golgi* : It is a fine delicate fibrillar network seen on the surface of the nerve cell. It is a pericellular reticulum which encloses the whole outer wall of the cell. Its fibrils can be traced into the dendrites and they are looked upon as nervous structures.

(10) *Deep Reticulum of Golgi* : It is a similar network seen in the deeper part of a cell. According to some authors they are composed of neuro-fibrils while according to others they are composed of investments derived from the neuroglia.

(11) *Pigment* : A clump of pigment granules, containing lipoids at one side of the nucleus. This is specially marked at certain localities give a distinct colour to the part, e.g., *Substantia nigra* of the mid-brain.

(12) *Membranous Sheath* : Each nerve cell is covered by a membranous sheath with nuclei upon its inner surface. This sheath is prolonged over the issuing fibres and is continuous with the neurilemma of the nerve fibres.

(13) *Axon Hillock* : This is a swelling in the cell body from which axis cylinder takes its origin. The Nissl granules are absent in this region.

(b) Nerve Processes (Nerve fibres) ; The nerve processes are of two types —axon and dendron.

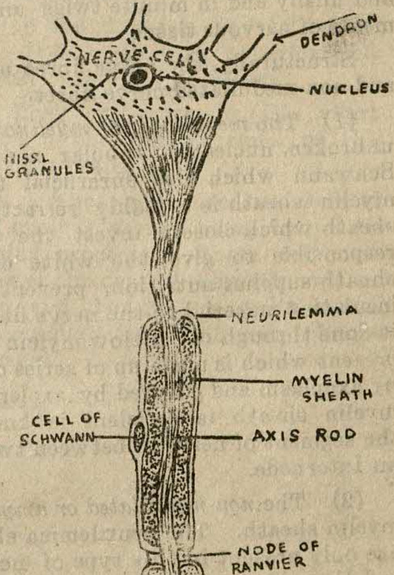


Fig. 11 Structure of a Typical Neurone

(1) *Axon or Neuraxon or Axis Cylinder* : It is the main single efferent motor process tends to be straight and long, contains no Nissl's granules. It is made up ofnumerous primitive fibrils, embedded in a semi-fluid neuroplasm. These fibrils are bound together with a very small amount of interfibrillar substance. It is surrounded by a relatively thick *myelin sheath* and a neucleated membranous *neurilemma sheath*. The myelin sheath is not a continuous process but there are interruptions at regular intervals. The gaps so produced are invaginated by the outer neurilemma sheath to give the appearance of constrictions called *Nodes of Ranvier*. In between the two nodes of Ranvier there is a single cell just underneath the neurilemma sheath called *Cell of Schwann*. The axon ultimately ends in an arborescence of fibrils in various end organs, sympathetic nerve cells etc.

(2) *Dendron or Dendrite or Protoplasmic Process* : It is multiple afferent sensory protoplasmic process of nerve-cell contains Nissl's granules. It is usually branch is a spreading manner with frequent bifurcations like the branches of a tree and finally end in minute twigs and become lost in other elements of nervous tissue

Structurally, the nerve fibres are of two types—medullated and non-medullated nerve fibres.

(1) The *medullated or myelinated nerve fibre* consists of an unbroken, nucleated, tubular neurilemma sheath or sheath of Schwann which lies surerficial to the myelin sheath. The myelin sheath is a highly refractile, whitish, double contour sheath which closely invest the axis cylinder process and is responsible to give the white colour to nerve. The myelin sheath supplies nutrition, prevents decepassion, serves as an insulating material to the nerve fibre and conduction of impulse is done through it. Below mylein sheath, the axis cylinder is present which is made up of series of parallel axis fibrils enclosed by axoplasm and covered by axolemma. The point where the myelin sheath is deficient is known as Node of Ranvier and the segment of nerve in between two Nodes of Ranvier is known an Internode.

(2) The *non-medullated or amyelinated nerve fibres* have no myelin sheath. The neurilemma sheath and the axis cylinder are only present in this type of nerve fibre. The optic nerve and the nerve tracts within the central nervous system have no neurilemma sheath and when any damage takes place in optic nerve, the process of regeneration fails. All post-ganglionic fibres are non-medullated fibres.

(B) Supporting Components of Nervous Tissue :

The neuroglia forms the supporting component of the nervous tissue. This is specialised forms of connective tissue cells found in association with the nervous system. The neuroglial cells are of four types—astrocytes, oligodendrocytes, ependymal cells and microglia or mesoglia. The first three types of cells are ectodermal in origin but the last one is mesodermal in origin.

(*a*) **Astrocyte** : It is found scattered throughout the central nervous system both in grey and white matters. They are of two types—protoplasmic astrocyte and fibrous astrocyte.

(1) The *protoplasmic astrocyte* is usually found in association with grey matter. It is made up of granular cytoplasm and rounded nucleus with numerous radiating branched protoplasmic processes.

(2) The *fibrous astrocytes* are found mostly in the white matter of the central nervous system. It is made up of numerous fibrillar cytoplasm and rounded nucleus with thick, larger, radiating unbranched protoplasmic process.

(*b*) **Oligodendroglea** : It is found more in the white matter than in grey matter. It is made up of spherical and darkly staining nucleus with scanty denditric processes.

(*c*) **Ependymal Cells** : They are more or less short columnar cells, found in the lining of the central canal of the spinal cord and the ventricles of the brain.

(*d*) **Microglea or Mesoglea** : These cells are mesodermal in origin. They consist of oval nucleus, scanty cytoplasm with numerous protoplasmic branching processes. These cells are usually found in the grey matter of the central nervous system close to the surface of the brain and also to the walls of the ventricles of the brain. The microglia cells are actively phagocytic and show amoeboid movement.

CHAPTER TWO

BIOPHYSICAL AND BIOCHEMICAL BASIS OF LIFE

Q. 1. What is Colloid? Describe the Properties and Physiological importance of Colloids.

Thomas Graham (1805-1869), the father of colloid chemistry, while studying the rates of diffussion of dissolved substances through parchment and similar membranes noticed in 1861 that some substances such as sugar, copper sulphate etc. readily passed through the membranes which crystalises and are termed as crystalloids, while gelatin, starch, glue which are non-diffusible materials upon evaporation yield amorphous solids and are often sticky in character which could not be crytallized were termed as colloids. The word Colloid is derived from the Greek word *kolla* meaning glue and *eidos*, appearance, i.e. glue-like appearance. A colloidal system comprises two phases, one of which is the continuous dispersions medium and the other, the discontinuous dispersed phase of particles with diameters above and below certain limits.

Classification of Colloids :

Colloids are divided into two main groups, depending on their ability to take up water.

(*a*) **Lyophilic** (Liquid-loving i.e. Solvent attracting) or *Emulsoid* or *Hydrophilic :* It is a system in which the colloidal particles have a high affinity for the dispersions medium and are combined with some of the medium or are solvated. A hydrophilic colloid system is a hyophilic system in which the dispersions medium is water. They are strach, agar-agar, egg-albumin, gelatin, haemoglobin, blood-proteins, etc.

(*b*) **Lyophobic** (Liquid-fearing i.e., Solvent repelling) or *Suspensoids* or *Hydrophobic* : It is a system in which there is little attraction between the colloid particles and the dispersions medium. A hydrophobic colloid system is a lyophobic system in which the dispersions medium is water. They are Gold, Silver, Platinum Mercury, Bismath, Sulphur, Ferric Oxide, etc.

Properties of Colloids :

(1) Optical Properties of Colloids :

Faraday-Tyndal Phenomenon : When a beam of light is admitted into a dark room through a small hole in the window shutters, the dust particles floating in the path of the light are

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rendered visible as shining specks of light by the scattering of the light waves at the surface of the floating particles. If the air of the room is free from dust, no shining particles will be seen and the beam of light will be invisible.

If, however, the same beam of light is passed through a colloidal solution, the path of the beam is rendered visible as a horizontal column of diffused light, like the sunbeam in the dark room. There the light is scattered from the colloid particles suspended in the liquid and is thus visible. This is called Faraday-Tyndall phenomenon or Tyndall effect.

(2) Brownian Movement :

In 1827, the Scottish Botanist, Robert Brown, while examining under the ordinary microscope suspensions of the pollen grains in water, noticed a continual oscillary and erratic movement of the pollen grains in all directions. The movement of the particles in suspension by the molecules of the liquid in which they are suspended.

Ludlum, Taft and Nugent observed that if drop of blood is taken from the finger before breakfast and examined under the dark-field microscope one may see many red corpulscles averaging 7 to 8 μ in diameter. The plasma from blood taken from the body a few hours after breakfast teems with bright particles dancing in Brownian movement.

(3) Electrical Properties of Colloids :

(*a*) **Electrophoresis or Cataphoresis** : Colloid particles are always electrically charged, some positively and others negatively. This is of fundamental importance that the colloidal systems would be very unstable without electric charges. The coarse suspensions or emulsions as well as the finely sub-divided colloidal particles carry their respective electric charge. The phenomenon of movements of colloids is known as Cataphoresis or Electrophoresis. By studying the electrophoresis of different colloids, they may be classified into electropositive and electronegative.

(*b*) **Iso-electric points** : By adding electrolytes to colloidal solutions a certain pH is reached when the electric charge of the colloid is neutralised, the positive ion acting on the negative colloid and the negative ion on the positive colloid. The pH at which this condition is attained is called iso-electric points. At the iso-electric point, the colloids become electrically neutral and appears to remain stationary in an electric field. The iso-electric point varies in different colloids e.g., the iso-electric point of egg albumin is at pH 4·8 ; of haemoglobin at

6·6 ; serum globulin at 5·4 ; gelatin at 4·7 ; casein at 4·7 ; and so on.

(4) Precipitation or Flocculation of Colloids :

(*a*) **Mutual precipitation of Colloids** : If the charge of one colloid is neutralised by the opposite charge of another by mixing them together in suitable proportions, aggregation of colloid particles, from a micron to sub-micron and thence to micron stage, takes place and thus result in flocculation and subsequent precipitation of the colloid.

(*b*) **Precipitation by electrolytes** : It has been observed that there is a potential difference of about 0·05 volt between different kinds of colloid particles and water in colloidal solutions. If this difference is maintained no precipitation takes place but if it is reduced by adding electrolytes of opposite signs to the colloidal solutions, the point of electric neutrality is reached and the colloid is precipitated.

(5) General Properties of Colloids :

(*a*) **Osmotic pressure of Colloids** : The osmotic pressure of colloidal solutions is very small in comparison with that of crystalloids, and it does not obey all the laws of osmotic pressure. The osmotic pressure of the colloids of blood serum containing 7-8% of proteins is only 25-30 mm. Hg, of a 1% solution of hæmoglobin at 0° is 2·6 mm. Hg.

(*b*) **Molecular weights of Colloids** : Colloids, specially the organic colloids have very high molecular weights. The colloids obtained by different methods of preparation may give different molecular weights, due to the formation of multimolecular colloid particles or micells. The mol. wt. of colloids represents therefore the weight of the micells, that is the "micellar weight." The following example of mol. wts. are interesting—Starch, 25000 ; Gum arabic, 2230 ; Colloidal tungstic acid, 1720 ; Albumin, 34500 ; Casein, 375000 ; Hæmoglobin, 68000, Serum globulin, 103500.

(*c*) **Protective action of Colloids** : When a gelatin solution is added to a gold solution, the particles of the emulsoid (gelatin) are absorbed by the particles of the suspensoid (gold), and the gold particles become much more resistant to precipitation. The precipitation of a suspensiod by electrolytes can be prevented or reduced by the addition of an adequate quantity of an emulsoid to a suspensoid solution. This is known as the protective action of colloid The protective colloids undoubtely play an important role physiologically. The proteins of milk serve as protective colloids to calcium phosphate aggregates and suspended in it. The bile salts and bile protein act as protective colloids to keep sparingly soluble cholesterol and the calcium salt of bilirubin in colloidal suspension. Gallstones may result from the precipitation of such substances in the absence of sufficient protective colloids. Protective colloids in urine may prevent bladder stone formation.

(*d*) **Peptisation or Deflocculation :** It is observed that a small amount of an electrolyte, if added to a colloidal solution of a lyophobe, produces its stabilization. For example, if hydrogen sulphide is passed through a suspension of freshly precipitated Silver sulphide it prevents the precipitation of the latter which is dispersed into colloid form and a stable colloidal solution of Silver sulphide is obtained. This process of prevention of flocculation of precipitation is known as deflocculation or peptisation.

(*e*) **Imbibition of water :** When a gel, for example, gelatin is placed in water, it takes up or imbibes a large quantity of the liquid, several times as large as the volume of the gel, and as a result of which it increases its volume to a considerable extent which is called swelling. The power of imbibing water by lyophilic colloids normally present in the blood is an important factor in maintaining its osmotic pressure.

(*f*) **Thixotropy :** (Gk. meaning change by touch). It has been found that a suspension in water of fine clays known as bentonites when shaken with a small quantity of an electrolyte gives a thin mobile solution, but on allowing it to stand for a few seconds, it sets to a semi-solid jelly. On shaking it vigorously three to four times, it liquefies again. This remarkable property is known as Thixotropy.

(*g*) **Prevaporation :** When a semipermeable sac containing a solution is suspended in a current of air, water is evaporated rapidly from the entire surface of the membrane. A protein digestion residue containing strong hydrochloric acid, histidine and enough humin to make it black was pervaporated. *Kobler* obtained sucrose crystals on the inside of a colloidan bag per crystallization of a 10% sugar solution, even the room temperatures and without fanning.

(*h*) **Coagulation :** Many colloids are sensitive to addition of small quantities of electrolytes, first becoming turbid and then coagulating. Such colloidal suspensions owe part of their stability to the like charges carried by the particles. When this charges are neutralised by ions of opposite charge, precipitation may occur,

Physiological Importance of Colloids : The colloids are of great physiological value and some of the examples are as follows:

(1) **Cell protoplasm :** The protoplasm of the cell exists in a colloidal state, mostly as emulsoid form.

(2) **Plasma, Milk and lymph :** These are all colloids and are emulsoid in form.

(3) **Interfacial reaction :** Colloids afford a very large surface area for various reactions to occur like adsorption, surface tension, enzyme action, etc.

(4) **Imbibition of water :** The emulsoid are readily imbibe water and thereby a good deal of water remains stored in the body.

(5) **Adsorption :** It is a colloidal phenomenon and has got great physiological importance.

(6) **Coagulation of blood :** It is a colloidal process during the phenomenon of coagulation, and sol (plasma) converts into a gel (clot) state.

(7) **Colloidal osmotic pressure :** When human red blood corpuscles are suspended in hypotonic saline solution (i. e. 0·5 gm% Nacl), water and sodium chloride pass into the cells due to lower osmotic pressure inside the cells causing swelling and bursting of the red cells. If the red cells are suspended in hypertonic saline solution (i.e. more than 1·0 gm% NaCl), water and salts pass out of the red cells which become shrunken and crenated. If the red cells are suspended innormal saline solution (0·9gm% NaCl), there is practically no change in the cells at all.

Q. 2. Write what do you known about diffusion, Dialysis, Osmosis, Hydrogen-ion-Concentration, Absorption and Adsorption.

Diffusion :

When two substances such as a solid and liquid or a liquid and a gas or two gases are kept in contact, the molecules of the two substances will pass into each other, until an uniform admixture is obtained. This phenomenon is known as diffusion. The molecules or ions of all substances in solution, gases or even dispersed particles in a colloidal system, tend to attain an equal distribution in terms of concentration through all parts of a system.

Physiological Significance :

(1) This process helps in the admixture of different food stuffs with the different types of digestive juices.

(2) It helps in the absorption of digestive food stuffs from the intestine.

(3) It serves the exchange of gases between plasma and red cells.

(4) The exchange of oxygen and carbon dioxide is preformed through the lung capillaries.

(5) In helps in the admixture of gases in the lungs.

Dialysis

It may be defined as a short of ultra-filtration of liquids on both sides separated by a porous membrane and the force acting is neither gravity nor hydrostatic pressure but it is purely osmotic pressure.

Physiological Significance :

(1) It enhances to pass on the bigger food particles from the intestine to the blood vessels during absorption.

(2) It does not allow to pass bigger albumin and globulin particles into the tissue fluid in the capillary area.

Osmosis and Osmotic Pressure :

The osmosis is meant that the spontaneous flow of water into a solution, or from a more dilute to a more concentrated solution when separated from each other by a suitable semi-permeable membrane, which is impermeable to the solute but is permeable to the pure solvent.

The osmotic pressure is defined as the excess pressure which must be applied to a solution to prevent the passage into it of solvent when they are separated by a semi-permeable membrane.

If the membrane separates to solutions of different concentrations, the stronger solution will be gradually diluted by the passage of water through the membrane from the weaker solution. The stronger solution is said to exert a higher osmotic pressure than the weaker solution.

Van't Hoff's Laws of Osmotic Pressure : The laws of osmotic pressure were deduced from Pfeffer's data by Van't Hoff and have been throughly verified by more accurate observations of Morse and of Berkely and Hartley. Van't Hoff's laws of osmotic pressure may be simply stated :

(1) The osmotic pressure of a solution varies directly as the concentration of a solute in the solution and is equal to the pressure the solute would exert if it were a gas in the volume occupied by the solution, if the volume of solute molecules relative to volume of solvent be negligible.

(2) The osmotic pressure of a solution of a given concentration is proportional to the absolute temperature, the volume kept constant.

(3) Equimolecular quantities of different substances when dissolved in the same volume of the solvent exert equal pressure as the same temperature, that is, equimolecular solutions are isomotic at the same temperature.

Physiological Importance of Osmosis :

(1) It helps in the absorption of digested food stuffs from the intestine.

(2) It serves exchange of gases in the capillary bed.

(3) It helps in the regulation of urine formation by the kidney.

(4) It increases the reabsorption of crebro-spinal fluid.

(5) The continuous osmotic exchange takes place between plasma and red blood cells.

Importance of Osmotic Pressure :

(1) It is of primary importance in the distribution of water and permeable solutes throughout both plants and animals.

(2) In general, water diffuses from the more dilute solution to the more concentrated solution in protoplasm because the membranes of the cells are permeable to it.

(3) Salts and other solutes diffuse from the more concentrated to the more dilute solutions in protoplasm if they can pass through the membranes.

(4) When the blood is diluted by drinking water, the diffusion pressure of water in the blood is increased and more water passes from the blood to the tissues.

(5) A patient may loose much water from his tissues and blood as a result of fever or other cause, and his blood and tissue fluid become much more concentrated than normal.

(6) The osmotic pressure of blood plasma, gastric juice, pancreatic juice, intestinal juice, liver bile and cerebrospinal fluid are approximately equal.

(7) According to De vries, when certain plant cells, having a supporting wall of cellulose around the protoplasm, are placed in solutions of high osmotic pressure, water passes from protoplasm to the stronger solution outside. This causes the protoplasm to shrink away from the cellulose membrane and the cells are said to be plasmolysed.

Hydrgen-ion-Concentration or PH

An acid may be defined as a substance which, when dissolved in water, produce hydrogen ions (H^+) and a base is a substance which produces hydroxyl ions (OH^-) when dissolved in water. A normal solution of an acid will exactly neutralise an equal volume of a normal solution of any base, no matter how strong or weak may be the charateristics of the two reactants. During neutralisation, equal numbers of hydrogen ions of acid and hydroxyl ions of base unite to from water. Total acidity or alkalinity is customarily expressed in terms of normality. It is also possible to use the normal system forexpressingthe concentration of hydrogen ions.

The chemist *Sorensen* was the first to device a method which is now universally accepted and followed all over the world to express the acidity or alkalinity of a medium with reference to hydrogen-ion-concentration. According to this method, pH 7 indicates neutrality. An increase in numerical value over 7, indicates alkalinity and a decrease below 7, means acidity.

The pH value of an unknown solution is determined with a fair degree of accuracy by matching the colour developed in the solution to be tested with buffer solutions of known Hydrogen-ion-Concentration containg the same indicator.

Physiological Importance :

(1) It maintains the acid-base balance of the body fluids,

(2) It helps to maintain the blood reation.

(3) It serves the formation and concentration of urine in the body.

(4) It regulates the reaction of enzymatic action during digestion and metabolism.

(5) The pH is one of the essential factors in determining the distribution of plants.

Absorption :

It is a physico-chemical process by means of which the digestive end products of different food stuffs are carried from the intestinal lumen to the blood vascular chamber through semi-permeable membrane with the help of various factors such as enzymes, co-enzymes, hormones etc.

Physiological Significance :

(1) The digestive end products are always carried from intestinal lumen to blood vessel for further circulation and proper utilisation.

(2) It takes place always through a semi-permeable membrane because bigger molecules can easily pass through it that will hamper the body system.

(3) It serves the function of nutrition of the body.

Adsorption :

It is a process by which substances adhere together on their surfaces. At the boundry surface between two phases which may be solid, liquid or gaseous, a change of concentration, brought about by the action of surface forces occurs. This change of concentration is known as adsorption. If the change leads to higher concentration, that is, an increased concentration of matter on a surface, it is called positive adsorption, whereas a decrease of concentration is known as negative adsorption which is shown by electrolytes in solution. The adsorbing material is called the adsorbent while the adsorbed substance is known as the adsorbate.

Huggins suggested that adsorption is purely a physical process and stated that the heat of adsorption is not a reflection or compound formation. In as much as the rare gases are positively adsorbed by charcoal and show a fairly high heats of adsorption e.g. argon 3450 cal/mole at 0°c as compared with 3645 cal/mole for nitrogen and 1870 Cal/mole for hydrogen at the same temperature.

Principles governing Adsorption :

(1) Gibbs-Thomson states "those substances which decrease surface energy tend to concentrate at a liquid-air interface and those substances which decrease interfacial energy tend to concentrate at a liquid-solid or liquid-liquid interface."

It follows from this principle that adsorption is best from solvents of high surface tension, because here the solute causes the greatest decrease in surface energy at the interface of adsorbing solid and liquid solvent.

(2) Adsorption is a reversible process. A condition of eqilibrium is reached for any given concentration of solute when it is in contact with the adsorbing agent.

(3) Adsorption decreases with rise in temperature due to the increased kinetic energy of the absorbed molecules, which causes them to escape more readily from the adsorbing surface.

(4) The adsorption process takes place relatively quickly and equilibrium is generally reached within one hour.

(5) The amount of adsorption is proportional to the surface area and it varies with the nature of the surface of the adsorbent and of the substance adsorbed,

(6) Adsorption is more nearly complete when the ratio of adsorbent to substance adsorbed is high.

(7) Narrow pores in the surface of the adsorbing agent and more effective than globular openings.

(8) The seat of adsorption may be very great.

(9) The molecules adsorbed on a surface are oriented and arranged in a definite manner relative to the adsorbing surface and to each other.

Physiological Importance of Adsorption Phenomena :

(*a*) **Adsorption and Catalysis :** Many chemical reactions are speeded up by the presence of adsorptive surfaces.

(*b*) Oxygen and hydrogen are adsorbed together upon platinum black and combine rapidly at ordinary temperatures to form water.

(2) Charcoal suspended in a solution of glycine, enables gaseous oxygen to oxides the glycine at ordinary temperatures.

(3) Enzymes, which are organic catalyst, are proteins and consequently collodial. They come in closer contact with the substrate while acting upon it. Surface adsorption upon the collodial enzyme particle is requiste for enzyme action.

(*b*) **Purification of Enzymes** : Adsorbing agents are widely used in purification process in industry, in the laboratory and are often applied in the purification of enzymes. The enzyme may be selectively adsorbed upon an agent.

(*c*) **Protoplasmic Organisation** : There are various more or less losely jointed complex compounds in protoplasm which are as combinations of proteins and lipids of various kinds, of proteins and salts, of proteins and carbohydrates, etc. It is known that such compounds are continually formed and broken down which enter vitally into the structure and function of living protoplasm. Adsorption processes very probably enter into the formation of some of these complexes.

(*d*) **Action of Drugs** : Adsorption plays a very important role in the action of certain drugs and poisons which are adsorbed upon cell surfaces and exert their effects there. Selective adsorption may be related to specific action.

Q. 3. What do you know about Buffers and Buffer System.

A buffer is one which tends to maintain a constant hydrogen-ion concentration even when a moderate amount of acid or alkali is added to it. A buffer solution consists of a mixture of a weak acid or a weak base and its salt. Buffers may be described as regulators or shock absorbers against sudden changes of pH. The essence of buffer action is the inhibition or damping down of the effect of addition of an acid to a solution by the production of another acid which ionises very slightly. Coversely, the inhibition of the effects of addition of an alkali through production of another alkali, which also ionises very slightly and much less than alkali added.

Buffers and Buffer Systems : Bicarbonates, acetates phosphates, borates, proteins, amino-acids, peptones etc, are some of the buffers having importance on biochemical and analytical problems.

Buffer systems are made up of buffer mixtures, each of which usually applies to a small range of pH, but by mixing three or more acids and acid salts or bases, buffer mixtures may be prepared covering a wide range of pH.

Different types of Buffers of the Body fluids and Tissues: A buffer is a chemical substance which prevents change of reaction of a medium. These are some of the important buffers present in the body fluids and tissues.

(1) Bicarbonate-carbonic acid buffers.

(2) Phosphate-phosphoric acid buffers.

(3) Non-volatile acid buffers

(4) Tissue buffers.

(5) Buffers of blood plasma.

(6) Buffers of red blood cells.

Description of Individual Buffers :

(*a*) **Bicarbonate-carbonic acid buffers :** These are the chief buffers of blood plasma. They are present in lymph and tissue fluids, tissue and red blood cells. The bicarbonate buffer is mainly concerned in neutralising the various acids produced by the tissue. It is directly linked up with respiration forming excess carbonic acid which is liberated through the lungs by the equation as :

Lactic acid $+ NaHCO_3 = Na -$ Lactate $+ H_2CO_3$.

(*b*) **Phosphate-phosphoric acid buffers :** These are present in the blood plasma in the ratio of 4 : 1 and help to maintain the blood reaction constant in co-operation with the kidneys. When an acid enters the blood, it becomes converted into acid phosphates in the following way :

Lactic acid $+ Na_2HPO_4 = Na -$ Lactate $+ NaH_2PO_4$.

The excess acid phosphate thus produced are liberated by the kidneys as acid urine. Similarly, an alkali enters the blood it becomes converted into alkaline phosphates and the excess alkaline phosphates thus produced are liberated as alkaline urine by the kidneys.

(*c*) **Non-volatile acid buffers :** When non-volatile acid enters the blood, they react with the anions of the buffer system and are neutralised. However, it is the bicarbonate-carbonic acid buffer system which is primarily concerned with such neutralisation

(*d*) **Tissue buffers :** The tissue cells help in regulating acid-base balance of the body through exchanging H^+, K^+ and Na^+ between the extra-cellular and intra-cellular fluids. In metabolic alkalosis, H^+ and K^+ shift from intracellular and extracellular fluids in exchange for Na^+, which enters the cells. It reacts with extracellular bicarbonate ion and forms carbonic acid.

(*e*) **Buffers of Blood plasma :** The protein buffers of blood plasma (albumin and globulin) are probably of greatest importance in tissue and in the blood. The plasma proteins remain mostly combined with sodium ion and help in buffer systems by two ways :

(1) As Sodium Proteinate :

$NaPr + \text{Lactic acid} = Na\text{—}Lactate + HPr$.

(2) As Carbamino—Compound formation :

$PrNH_2 + CO_2 = PrNHCOOH$.

(*f*) **Buffers of Red Blood Cells :** The red cells or erythrocytes of blood are heavily buffered, chiefly as a result of the presence of large amounts of the protein heamoglobin. Haemoglobin is an important protein buffer found in red blood cells and is very efficient to deal with carbonic acid. It is known how in the, "chloride shift", carbon dioxide from the tissues diffuses into the red blood corpuscles and is converted into carbonic acid by carbonic anhydrase. Carbon dioxide diffuses from the red blood corpuscles to the plasma and then to the alveolar air. The buffering action of haemoglobin is illustrated as follows :

(1) As Potassium Haemoglobinate,

$HHb + KOH = KHb + H_2O$

$KHb + H_2CO_3 = HHb + KHCO_3$.

(2) As Carbamino-Compound formation.

$HbNH_2 + CO_2 = HbNHCOOH$.

Q. 4. What is meant by Oxidation and Reduction ? Briefly discuss the oxidation reduction system operating in physiological processes.

The term oxidation was originally used for the process in which there is fixation of oxygen. With the elaboration of the idea, it is now considered that oxidation should include (1) Loss of electron. (2) Loss of hydrogen atoms and (3) Addition of oxygen. The inverse processes are termed as reduction. Respiration is a unique example of oxidation in biological process. The process of oxidation and reduction run side by side. When a substrate is oxidised, the oxidising agent itself is reduced because either it donates oxygen or takes out hydrogen.

In tissue respiration, the oxidation process progresses stepwise and at the final stage it is oxidised by addition of oxygen producing water. The stepwise reactions are accomplished with the help of some agents which are generally some enzymes.

Chemicals playing important role in oxidation reduction system :

I. **Cytochrome System :** The cytochrome is a group of pigments, composed of an iron-containing haematin compound combined with another unknown nitrogenous body, known as haemochromogens.

By spectroscopic means, there are three closely related substances which are cytochromes A, B and C. In the living cells, cytochromes can be seen to undergo alternate oxidation and reduction. The oxidised cytochrome gives up its oxygen to the substrate and itself becomes reduced. The reduced cytochrome takes up oxygen from outside and becomes oxidised again and in such a way, cytochrome works as a catalyst. The reduction of oxidised cytochrome is helped by a dehydrogenase, which takes away hydrogen from the substrate and gives it to the oxidised cytochrome acts both as a hydrogen acceptor as well as oxygen carrier. Warburg's respiratory enzyme or Indophenol oxidase or Cytochrome oxidase in the presence of molecular oxygen, oxidises reduced cytochrome C as hydroquinone.

II. **Glutathione** : The glutathione is a tripeptide of glycine and glutamic acid and is γ-glutamyl cysteyl-glycine. It exists in two forms such as oxidised and reduced from. On oxidation, cysteine may be converted into disulphide form or cystine.

Glutathione though present in minute quantities in the intracellular fluids of animal tissue as well as in plants, yeasts and many bacteria, it plays an important role in the process of oxidation and reduction which occur in the cells. Since, under suitable conditions, it can function either as a hydrogen acceptor or as an oxygen carrier.

III. **Warburg's yellow oxidising enzymes**: The catalytically active flavoproteins of Flavin dinucleotides or yellow enzyme, which can exist in both the oxidised and the reduced state was first shown by *Warburg* in 1932. Chemically, it consists of flavins phosphoric acid and a protein, the flavin being identical with riboflavin, or vitamin B_2. This substance actually occurs in cells in combination with protein is a flavin-adenine-dinucleotide or alloxazine-adenine dinucleotide, of which the yellow enzyme is a decomposition product. TPN-Cytochrome C reductase and DPN-Cytochrome C reductase are yellow enzymes. The dinucleotide can undergo reversible oxidation and reduction, and so act as an oxygen carrier ; the reduced form is called leuco-flavoprotein The yellow enzyme or flavoprotien, often acts on part of a double enzyme system, the other part being a DPN-enzyme complex. Thus,

DPN H_2 + Flavoprotein→DPN + Leuco-flavoprotein.

The DPN so regenerated can again be reduced and so oxidise a further molecule of substrate. Meanwhile leuco-flavoprotein can be re-oxidised in two steps : first a "Carrier" is reduced and thereby leucoflavoprotein is oxidised ; then the reduced carrier takes up free oxygen and is converted into oxidised form. The whole cycle of changes involving DPN and flavoprotein, with their specific protein partners would thus be :

Substrate + DPN → Oxidised substrate + DPN $\dot{H}_2$

DPN·H_2 + Flavoprotein → Leuco-flavoprotein.

Leuco-flavoprotein + Carrier → Flavoprotein + Reduced Carrier.

Reduced carrier + O_2 → Carrier.

IV. **Xanthine Oxidase** : This enzyme is found chiefly in the liver and oxidises xanthine to uric acid. The xanthine oxidase contains molybdenum in addition to flavin-nucleotide and catalyses the oxidation of hypoxanthine to xanthine and of xanthine to uric acid. Xanthine at first combines with water forming xanthine hydrate. The hydrate loses two hydrogen atoms forming uric acid. The two hydrogen atoms then unite with one molecule of oxygen to form H_2O_2. The latter is broken down by the enzyme "Catalase" to form water and free oxygen.

V. **Luciferase and Lipoxidase** : These are the two oxidising enzymes. Lipoxidase is responsible for the formation of a peroxide by the addition of a molecule of oxygen to the double bonds of certain unsaturated fattyacids such as linoleic and lenolenic acids. The peroxide may then being about the oxidation of cartenoids and Vitamin A.

VI. **Electron System** : The modern chemical theory of tissue oxidation is the fundamental process involved in electron tranformer. A hydrogen atom removed during a dehydogenation reaction undergoes "acidic ionisation", to give a proton and an electron. The term oxidation is applied to a reaction in which a substance loses electrons, similarly, a gain of electrons, is termed as reduction. The reduced cytochrome oxidase has the unique property of transferring an electron to molecular oxygen. Protons from the intial ionization then react with the negatively charged oxygen to give water.

Q. 5. Define a Catalyst and an Enzyme. What is the classification of enzyme ? Discuss the characteristics or properties of enzyme actions. Describe the various factors which influence enzymatic action.

A *Catalyst* is a substance which influence the rate of a chemical reaction without itself undergoing any chemical change or any change in amount during the reaction. The process of such chemical reactions is known as *catalysis*.

An *Enzyme* is a non-living, nitrogenous, amorphous, organic, complex colloidal biological catalyst produced by the living cells but independent of the presence of the living cells in their action which itself remains unchanged after the reaction is over but it acts specifically only upon substances whose molecules have a certain definite stuctural and sterochemical arrangement.

Classification of Enzymes : Enzymes have been classified by different ways producing much confusion in the minds of the beginner. The most simplier type of classification is discussed below :

I. **Hydrolysis-Condensation Type** :

(a) *Esterases* : These are ester hydrolysing enzymes. These include Pancreatic lipase, Gastric lipase, Plant lipase, Liver esterase, Choline esterase, Chloropyllase etc.

(b) *Phosphatases* : The acid and alkali phosphatase include Hexose monophosphatase, Hexakinase or Transphosphatase, Nucleotidase, Lecithinase, Phytase, Pyrophosphatase, Adenosine-triphophatase (myosin), Thiamine pyrophosphatase etc.

(c) *Proteinases and Peptidases* : Proteinases attack central peptide linkage and peptidases attack terminal peptide linkage. They include Pepsin, Trypsin, Chymotrypsin, Rennin, Protaminase, Papin, Cathepsins, Carboxypeptidase, Aminopeptidase, Dipeptidase etc.

(d) *Carbohydrases* : These are carbohydrate hydrolysing enzymes. These include Amylase or Diastase, Cellulase, Inulase, Maltase. Sucrase or Invertase, Lactase etc.

(e) *Glucosidases* : These include Myosin, Emulsin, Linase, Dhurrase etc.

(f) *Aminases or Amidases* : These act on carbon-nitrogen linkage in non-protien compounds and the nitrogen is liberated as ammonia. These include Urease, Adenase, Guanase, Arginase, Glutaminase, Hippuricase, etc.

II. **Phosphorylysis-Condensation Type** : The phosphorylases enzymes are found in the liver, heart muscle, brain, yeast, potato etc. The chemical reactions are reversible.

III. **Cleavage Type** : It includes Decarboxylases, Carboxylases, Aldolases etc. They function in the presence of the Co-enzyme and Co-carboxylase. Those acting on keto-acids are called Carboxylases and others are called Decarboxylases. They include Carboxylase, Vegetable Carboxylase, Oxaloacetic carboxylase, Amino-acid dacarboxylase, Carbonic anhydrase etc. The aldolases include Aldenhyde oxidase, Aldenyde Mutase, etc.

IV. **Oxidation-Reduction Type** : They are concerned in biological oxidations and simply oxidation-reduction systems. They include the following :

(a) *Oxidases* : These bring about oxidation in presence of molecular oxygen which in turn reduced to hydrogen peroxide. These include Tyrosinase, Monophenol oxidase, "Dopa" oxidase, Polyphenol or Catechol oxidase, Lacease, Glyoxalase, Cytochrome oxidase, Xanthine Oxidase, Uricase or Uric acid oxidase etc.

(b) *Peroxidases* : These bring about oxidation by transfer of oxygen in active form from hydrogen peroxide to the substrate. These include Peroxidases which are iron-porphyrin-protein compound.

(c) *Dehydrogenases* : These catalyse oxidation indirectly by the transfer of activated hydrogen from the substrate to an acceptor, Their action is inhibited by narcotics but not by cyanides These include Lactic dehydrogenase, Succinic dehydrogenase, Malic dehydrogenase, Beta-hydrobutyric dehydrogenase, Citric dehydrogenase, Alcohol dehydrogenase, Glycerophosphate dehydrogenase, Glucose dehydrogenase, etc.

(d) *Catalases* : These bring about decomposition of hydrogen peroxide into water and molecular oxygen. They include Catalase which is an iron-prophyrin-protein compound.

V. **Hydration-Dehydration Type** : It includes Hydrase and related enzymes such as Aconitase, Fumerase etc.

Properties or Characteristics of Enzyme Actions : There are some special properties whfch deserve careful consideration, are the following: ·

(a) **Solubility** : The enzymes are solute in water, dilute glycerine, dilute alcohol and saline except some fat splitting enzymes obtained from plant seeds.

(b) **Specificity** : They exhibit specificity in their ability to accelerate chemical reactions. This means that a given catalyst is limited in its catalytic activity to a more or less restricted type of chemical reaction.

(c) **Senisitivity** : They are much more sensitive to variations of temperature of pH and of electrolytes. They are highly sensitive to specific factors such as co-enzymes, activators, poisons and toxins. All enzymes are inactivated or killed by boiling in aqueous solution (60° to 100°C). The pH range of enzymes varies from about 1·5 for pepsin to about 10 for trypsin, but the majority act best within pH 4·5 to pH 7·5. They are readily destroyed by long exposure to light, particularly to ultraviolet or lights of still shorter wave lengths.

(d) **Catalytic activity** : They are unchanged in the reaction. This property of ideal catalysts can only be proximated by enzymes that are completely stable under the conditions of an experiment. If present in small amount relative to the substrate ; an ideal catalyst does not affect the equilibrium of a reversible chemical reaction and the function of the catalyst to hasten the process in either direction.

(e) **Colloidal Property** : Enzymes are basically protein and so the molecular dimension is so large that it shows colloidal properties.

(f) **Reversibility Reaction :** Enzymes can break any substrate as well as can synthesise the substance from the end products. This property is known as reversibility of reaction. For example, the enzyme lipase can break down fat into fatty-acid and glycerol, as well as can synthesise fat by condensation of fatty acid and glycerol.

Factors Influencing Enzymatic Action : The following are some of the important factors which influence enzymatic activities :

(a) **Concentration of enzyme :** The velocity of an enzyme reaction is directly proportional to the concentration of the enzyme.

(b) **Concentration of the substrate :** The volocity of an enzyme reaction increases as the concentration of the substrate increases.

(c) **Hydrogen-ion-Concentration :** The velocity of reaction is markedly influenced by hydrogen-ion-concentration of the medium. The optimum pH depends on various conditions such as the nature of the buffer used, the nature of the substrate, the source of the enzyme etc.

(d) **Effect of temperature :** The velocity of an enzyme reaction may be four times the initial value with each 10°C rise in temperature until the optimum temperature is attained. If the higher temperature reaches than the optimum temperature, the velocity of reaction decreases and ultimately stop due to inativity of the enzymes.

(e) **Products of reaction :** The more the accumulation of the products of reaction, the less is the velocity of reaction. This may be dne to the reversible reaction and the products of reaction combining with the enzyme because of their structural similarity to the substrate.

(f) **Effects of Radiant energies :** Enzyme activities may be accelerated or retarded by light rays. Red and blue light accelerate the action of salivary amylase and several other enzymes, where as the ultraviolet rays and radium emanations produce the opposite effect.

(g) **Activator :** There are some activators like manganeese, magnesium, cobalt, nickel, chlorine etc. which activate the enzymatic reaction.

(h) **Inhibitor** : There are some chemicals which inhibit enzymatic activity. They mainly block the active region of the enzyme which is to be occupied by the substrate and thus makes the enzyme inactive.

Q. 6. What is Protoplasm ? Describe birefly the composition of Protoplasm.

Protoplasm is a complex, polyphasic, colloidal, translucent substance which is the entire material contained in a cell. It can be distinguised clearly as nucleus and cytoplasm. All the vital functions and expressions of life occur through the protoplasmic medium and so *T. H Huxley* in 1868, defined protoplasm as 'the Physical Basis of Life''. All the properties of life are manifested on the continuous activities in protoplasm.

Composition of Protoplasm : The essential substances in our food stuffs are the ingredients of protoplasm.

(a) **Physical Properties** : Protoplasm is a translucent, grayish slimy substance, clear, optically homogeneous fluid saturated in a high percentage of water, somewhat viscous but capable of flowing. The *specific gravity* of protoplasm is slightly above that of water in which a large number of minute granules and globules of varying size and shape remain distributed. It is a viscous and elastic fluid. Protoplasm is a complete *colloidal system* and may be either a somewhat rigid *gel* or a more liquid *sol*, and in living matter this states may interchage during metabolic processes. Colloids do not diffuse through parchment or similar membranes and upon during ordinarily yield formless masses, where as crystalloids such as salts or sugars usually form true solutions that can diffuse through membranes and upon drying yields crystals of definite structure.

(b) **Chemical Composition** : To live one must have water and three basic food stuffs namely carbohydrates, proteins and fats. In addition to these there should be certain salts and some special organic substances like vitamins. Protoplasm consists of all the substances, of them water is present abundantly and proteins remain in large amount. Carbohydrates and lipids are also essential constituents of protoplasm. In addition, protoplasm contains many electrolytes, some rare elements and special organic capounds like hormones and vitamins, in variable amount.

Basic Physiological Properties or Functions of Protoplasm.

By virtue of the different constituents of protoplasm, the following physiological properties are exhibited. These are :

(1) **Irritability** : It is responsible for a cell to be stimulated.

(2) **Conductivity :** The ability for the transmission of stimuli.

(3) **Contractility :** The ability of protoplasm to be shortened in any direction.

(4) **Absorption, Phagocytosis and Assimilation :** The ability to take some dissolved substance in protoplasm is absorption which is generally selective. When any particular substance is taken up, it is called phagocytosis. The utilization of this product of absorption and phagocytosis is called assimilation.

(5) **Excretion and Secretion :** The ability to give out waste products is excretion. When any useful substances are given out, it is called secretion.

(6) **Respiration :** The abillty to oxidise carbon by oxygen through which energy is derived is called respiration.

(7) **Growth and Reproduction :** When the protoplasm increases in amount, it is called growth. The capacity of producing replica of its own is termed as reproduction.

Q. 7. "Is Protoplasm a Colloid"—Explain.

That protoplasm is a colloid can be proved by the following discussions :

(1) The protoplasm and colloid have a *dispersed* or *discontinuous phase* and a *dispersion* or *continuous phase*. They are also called suspensoid or emulsoid when large insoluble particles lie as suspension in the continuous phase. The solid and jelly-like apperance are the common properties of a colloid and protoplasm.

(2) *Imbibition* is one of the important properties of protoplasm which is the characteristic feature of colloids. It is nothing but a physical process of diffusion between two liquids, one of which remains inside the imbibant and the other outside it.

(3) Both colloids and protoplasm have the property of *adsorption*. It is the power of retaining a very fine film of moisture or gas by the surfaces of various matters.

(4) *Brownian movement* is also a character which is shared by both protoplasm and colloids. It is the character of the dispersed phase that they are constantly in a state of motion.

(5) *Tyndall phenomenon* is also exhibited by both colloids and protoplasm. If a beam of light is passed through a colloidal system and then observe at right angles, the dispersed particles will be seen scattering it as a visible beam of light.

(6) The *electrical properties* of protoplasm and colloids help in the process of absorption of ionized salts by the roots of a plant.

(7) The colloids and protoplasm possess various degree of *viscosity*. The viscosity is nothing but a resistance encountered by the fluid during its flow.

(8) *Flocculation* is a state when particles of many colloids are made to aggregate or settle down by the application of ionized substances.

Q. 8. What is Isotope ? Describe the natural and radioactive isotopes. Discuss the physiological importance of Isotopes.

The isotopes and atoms of the same elements whose nuclei contain different numbers of neutrons but the same number of protons.

Natural Isotopes : They are remain as mixtures in all natural sources and can be easily isolated careful fractionation. The isotopes of physiological importance are generally *carbon, hydrogen, nitrogen, oxygen, sulphur, chlorine*, etc. For example, carbon having the atomic weight 12, has isotopes with atomic weight 11, 12, 13 and 14 and it is written as C^{11}, C^{12}, C^{13}, C^{14}. Hydrogen has the usual atomic weight 1, but isotopic heavy hydrogen has an atomic weight 2 and it is written as ${}^{2}H$. Oxygen with atomic weight 16, has isotopes with atomic weight 17 and 18 and it is written as ${}^{17}O$, ${}^{18}O$. Sulphur with atomic weight 32, has isotopes with atomic weight 33 and 34 and it is written as ${}^{33}S$, ${}^{34}S$ and chlorine with the usual atomic weight of 35 may have an isotopic variety with 37 and it is written as ${}^{37}Cl$. The deuterium and triterium have hydrogen isotopes as ${}^{2}H$ and ${}^{3}H$ respectively. D_2O (Deuterium oxide) is the heavy water is present throughout the body fluids.

Radioactive Isotopes : The elements like radium and uranium are radioactive which emit α-, β and γ- rays. The majority of the naturally occurring elements are not radioactive. The radioactive isotopes can be prepared artifically by bombardment with a *cyclotron*. The α- radiation is not easily detected. The β-radiation and γ- radiations are usually measured with *Geiger-Muller Counter*. The stability of a radio-active isotope can be measured by its *half-life*, which is the time taken by the radiation to come down to help the original strength.

Physiological Importance of Isotopes : The isotopes, either natural or radioactive, have been extensively used in many other physiological functions which are mentioned below : (1) It helps in the measurement of red cell volume of the body. (2) It serves in the determination of plasma volume of the blood. (3) It helps in the estimation of total body water. (4) It determines the extracellular space. (5) It helps in study of absorption of different food stuffs through gastro-intestinal tract. (6) It is essential for the study of metabolism of protein, carbohydrate, lipid and minearls. (7) It helps to study the movement of substances across cell membrane (8) It determines the rate of production and metabolism of different hormones. (9) It is extensively used in different physiological and clinical studies in recent times.

Q. 9. What are Proteins ? How they are Classified ?

Proteins are most complex nitrogenous organic substances essential for all known biological materials which are found in all animal and vegetable cells. They are composed of mainly carbon, hydrogen, oxygen and nitrogen and sometimes sulphur and phosphorous also enter into their composition. Chemically, proteins are typical amphotoric substances i.e., they are both acids and bases, uniting with acids to diminish their acidity and with bases to diminish their alkalinity. Protein is the condensation product of amino-acid molecules having peptide linkage which gives Biuret reaction.

Classification of Proteins : The classification of proteins is based under specified experimental conditions which exhibit certain characteristic properties. A brief outline classification of proteins are :

I. Simple Proteins : They consist of a mixture of amino-acids and yield only α-amino-acids or their derivatives on hydrolysis. They also yield carbohydrates.

(a) Coagulable by heat.
  1. Soluble in water—Albumin.
  2. Insoluble in water—Globulin, Glutelin.

(b) Not Coagulable by heat.
  1. Soluble in water—Protamine, Histone.
  2. Insoluble in water—Prolamine, Gliadin, Scleroprotein or Albuminoids.

II. Conjugated Proteins : They consist of simple protein molecule remain combined with some non-protein prosthetic substances. They are classified according to the nature of the prosthetic group below :

(a) Phosphoric acid splitting—Nucleoprotein, Phosphoproteins, Lecithoproteins, Lipoproteins. etc.

(b) No phosphoric acid splitting—Glycoproteins, Chromoproteins, Metalloproteins, etc.

III. **Derived Proteins** : These are intermediate products of protein hydrolysis by the action of acid, alkali, heat and enzymes.

(a) **Primary Protein Derivatives** : These are substances, formed from some of the simple and conjugated proteins on denaturation. They are *Proteans*, *Metaproteins* e g., acid metaprotein (acid albminate) and alkali metaprotein (alkali albuminate).

(b) **Secondary Protein Derivatives** : These are substances formed during the hydrolysis of the protein molecule. They are *Proteoses* e.g, Primary proteoses and Secondary proteoses, *Peptones*, *Peptides* e g., dipeptides, tripeptides, tetrapeptides pentapeptides, etc. and *amino-acids*

I. Simple Proteins.

These proteins are simpler in constitution. The improtant members of this group are given below :

(1) **Albumins** are soluble in distilled water and coagulated by heat, acids and alkalies. It is precipitated by full saturation of ammonium sulphate. It has the general nutritive power of the body for glandular secretion. It includes egg albumin in egg, lact albumin in milk, serum albumin in blood, lymph and tissue fluid, myo-albumin in muscle and legumelin in peas, beans and lentils etc.

(2) **Globulins** are insoluble in distilled water but soluble in dilute neutral salt solution. It is coagulated by heat and precipitated by full saturation with magnesium sulphate and half saturation with ammonium sulphate. It includes serum globulin in plasma, egg-globulin in egg white, fibrinogen in plasma, myogen in muscle, crystalline in the crystalline lens of the eye and vegetable proteins in the beans, maize etc.

(3) **Glutelins** are insoluble in water, soluble in hot water and become coagulated by the application of heat. It is found mostly in food stuffs like Wheat, Bazra, Joar, in other cereals. They may be mixtures of denaturated proteins.

(4) **Protamines** are soluble in dilute ammonium hydroxide solution and not coagulated by heat. They are found in the spermatozoa of certain fishes in combination with nucelic acid. They include Salmine in spermatozoa of salmon, Sturine in spermatozoa of sturgeon, Clupeine in spermatozoa of herring fish and Cyprinine in spermatozoa of cary fish.

(5) **Histones** are soluble in water, dilute acids and alkalies but insoluble in ammonia. They are not coagulated by heat and strongly basic in character. They are found in the embryo,

eggs of the lower animals like fishes, frogs etc. and in the head region of spermatozoa of higher animals.

(6) **Prolamines** are insoluble in water, neutral solvents and absolute alcohol but soluble in 70% to 80% alcohol. They include Gliadin in wheat Zein in corn, Hordein in barley etc. It has contained a good supply of nitrogen and has got a good biological value.

(7) **Gliadins** are soluble in 70% to 80% alcohol but insoluble in distilled water. They are not coagulated by heat. They are found 5% to 8% in rice, 9% to 11% in wheat etc

(8) **Scleroproteins** (albuminoids) are insoluble in cold water or in any cold reagent but soluble in strong acids and prolonged heat. They include keratin in hoofs, nails, horns, nails, elastin in elastic tissue, cartilage and ligament, collagen in white fibrous tissue, bone and cartilage and neurokeratin in neuroglia of the central nervous system.

II. Conjugated Proteins.

In these compounds, a simple protein molecule remains conjugated with another non-protein prosthetic group conferring new and characteristic properties. They are classified according to the nature of the prosthetic group, as indicated below :

(1) **Nucleoproteins** contain simple protein like protamines or histones and the non-protein prosthetic group is the nucleic acid. The nucleic acid of the cell nucleus appears to be deoxyribose nucleic acid which is united to the protamines, histones, and other basic proteins of the cell nucleus. The nucleic acid is made up of four mononucleotides. Each mononucleotide is composed of a phosphoric acid, a pentose carbohydrate called ribose and the nitrogenous bases like purine and pyrimidine. The purine base is composed of adenine and guanine and the pyrimidine base is made up of thymine and cytosine in aniamals and cytosine and uracil in vegetable nucleoprotein.

(2) **Phosphoproteins** contain simple protein and the non-protein prosthetic group becomes phosphoric acid. They are insoluble in water, rendered soluble in dilute acids, easily soluble in dilute alkalies and with acids again the original body is precipitated. They include Caseinogen in milk and Vitellin in egg yolk. The Ovo-vitellin contains a large amount of lecithin in the lecitho-nucleo-protein complex.

(3) **Lecithoproteins** contain simple protein and the non-protein prosthetic group becomes lecithin that belongs to the group of phospholipids. They are found in eggs, brain, blood-serum etc.

(4) **Glycoproteins** contain simple protein molecule that remains combined with the non-protetn prosthetic group of carbohydrate radicle cantaining nitrogen like glucosamine or galactosamine. They are found in the mucin of the saliva, connective tissues, intestinal secretions and bile. They are not coagulable by heat, precipitated by acid and the precipitate redissolves with alkali.

(5) **Sulfomucins** contain sulfuric acid, uronic acid and either chondrosamine or glucosamine. They are found in cartilage, intestinal tissue, cornea, gastric mucosa etc.

(6) **Chromoproteins** contain the simple protein molecule that remain combined with the non-protein metal containing prosthetic group like colouring matters. They include red iron-containing haemoglobin in red blood corpuscles, visual purple in the retina, flavoprotein in riboflavin, blue copper-containing haemocyanin in the blood pigment of crustacea and green magnesium containing chlorophyll in the green colouring matter of the plants.

(7) **Metalloproteins** are various protein enzymes which contain metals such as tyrosinase contains copper, arginase contains manganese or magnesium, carbonic anhydrase contains zinc, xanthine oxidase contains molybdenum etc.

III. Derived Proteins.

These proteins are not present in nature. They are found as products of hydrolysis of the native protein molecules. These are produced by the action of acids, alkalies or proteolytic enzymes upon certain proteins.

(1) **Proteans** are probably an early denaturation stage. These are insoluble products which apparently result from the incipient action of water, very dilute acids or enzymes—e.g., fibrin from fibrinogen, myosan from myosin, edestain from edestin.

(2) **Metaproteins** are the first product of hydrolysis. They are coagulated by heat, soluble in excess of dilute acid or alkali and insoluble and precipitated at the iso-electric point. Metaproteins are of two varieties—acid and alkali metaproteins.

(3) **Proteoses** are the second product of hydrolysis from metaproteins formed by the action of pepsin or trypsin upon protens. They are soluble in water, weak salt solutions, acids and alkalies and not coagulated by heat giving violet biuret reaction. Proteoses are of two types—Primary proteoses and Secondary proteoses.

(4) **Peptones** are derived from proteoses. They give a red biuret reaction and not coagulable by heat. They are soluble in

water and generally soluble in alcohol. They may be precipitated by tannic acid, phosphotungstic acid, phosphomolybdic acid etc.

(5) **Polypeptides** are derived from peptones on further hydrolysis. They do not give biuret reaction, coagulation reaction and precipitation reaction.

(6) **Lower peptides** are hydrolysed product of polypeptides.

(7) **Amino-acids** are the final hydrolysed product of protein or protein digestion. They do not respond to biuret test.

Q. 10. What are the Amino acides ? How are they classified ?

Amino-acid, an amino-derivative of fatty acid, is a final digestive end product of protein. Chemically, an anino-acid may be considered to be derived from an organic acid in which one or more H-atoms is in the chain are replaced by an amino (NH_2) group, although there may be two exceptions—proline and hydroxyproline.

Classification of Amino-acids. The amino-acids may be classified according to the number of their amino-acid and carboxyl groups.

I. Alephatic amino-acids :

A. Neutral amino acids :

(a) Mono-amino-carboxylic acids : They contain one amino and one carboxyl group. (1) Glycine, $C_2H_5O_2N$ or Aminoacetic acid or Glycocoll. (2) l-Alanine, $C_3H_7O_2N$ or α-aminopropionic acid. (3) l-Leucine, $C_6H_{13}O_2N$ or β-isopropyl-alanine or α-amino-isocaproic acid. (4) d-Isoleucine, $C_6H_{13}O_2N$ or β methyl-β ethylalanine or β-methyl-α-aminovaleric acid. (5) d-Norleucine or α-aminovaleric reid. (6) l-Methionine, $C_5H_{11}O_2NS$ or α amino-γ-methylthiol-n-butyric acid. (7) d-Threonine, $C_4H_9O_3N$ or α-amino-β hydroxy-n.butyric acid. (8, d-Valine, $C_5H_{11}O_2N$ or $\beta\beta$-dimethylalanine or α-amino-isovaleric acid. (9) d Norvaline or α-amino-valeric acid. (10) l-Serine, $C_3H_7O_3N$ or β-hydroxyalanine or β hrdroxy-α-amino-propionic acid. (11) Iodogorgoric acid. (12) l-Thyroxrne.

(b) Diamino-dicarboxylic acids or Sulphur containing amino-acids : They contain two amino and two carboxyl groups.

(1) l-Cystine, $C_6H_{12}O_4N_2S_2$ or di-cysteine.

(2) l-Cysteine, $C_3H_7O_2NS$ or β thiol-alanine or β-thiol-α-amino-propionic acid

B. **Acidic amino-acids** or Mono-amino-dicarboxylic acids. They contain one amino and two carboxyl acids.

(1) l Aspartic acid, $C_4H_7O_4N$ or α-amino-succinic acid.

(2) d Glutamic acid, $C_5H_9O_4N$ or α-amino glutaric acid.

(3) d-Hydroxy-glutamic acid or α-amino-β-hydroxy-glutamic acid.

C. **Basic amino-acids** or di-amino-mono-carboxylic acids : They contain two amino and one carboxyl group. (1) d-Arginine, $C_6H_{14}O_2N_4$ or δ-guanidino-α-aminovaleric acid. (2) d-Ornithine or α δ-diamino-valeric acid. (3) Citrulline, $C_6H_{13}O_3$ or δ-carbamino-α-aminovaleric acid. (4) d-Lysine, $C_6H_{14}O_2N_2$ or α-ε-diamino-caproic acid.

II. **Aromatic amino-acids :** (1) l-Phenylalanine, $C_9H_{11}O_2N$ or β-phenyl-α-amino-propionic acid. (2) l-Tyrosine, $C_9H_{11}O_3N$ or β-parahrdroxy-phenyl alanine.

III. **Heterocyclic amino-acids** : (1) l-Histidine, $C_6H_9O_2N_3$ or α-imidazole-alanine, (2) l-Tryptophan, $C_{11}H_{12}O_2N_2$ or β-3-indole-alanine.

IV. **Condensed amino-acids** :

(1) l-Proline, $C_5H_9O_2N$ or α-pyrrolidine-carboxylic acid,

(2) l-Hydroxyproline, $C_5H_9O_3N$ or 4-hydroxy-pyrrolidine. 2-carboxylic acid.

V. **Newer Amino-acids** : The following amino-acids are isolated and identified by the paper chromatography and nutritional test method. (1) α Aminobutyric acid. (2) Lanthionine or Thiodialanine. (3) Cystathionine. (4) Ergothioneine. (5) 3,5 3 Triiodothyronine. (6) Methioninesulfoximine. (7) Tabtoximine or α-ε-Diaminy-β-Hydroxypimelic acid.

Q 11. What do you mean by Essential and Non-essential Amino-acids ?

According to the necessity for the growth and health of a growing human being, amino-acids are classified into essential and non-essential one.

The essential amino acids are those amino-acids which are required for the growth of the body but the body is unable to synthesise it. They are ten in number, such as d-histidine, d-isoleucine, l-leucine, d-lysine, l-methionine, d-arginine, l-phenylalanine, l-tryptophan, d-valine and d-threonine.

The non-essential amino-acids are those amino-acids which are not required for the body building purposes but the body can sythesise it very easily. They are glycine, d-alanine, l-serine, d-norvaline, l-aspartic acid, d glutamic acid, d-hydroxy-glutamic acid, d-ornithine, citrulline, l-cysteine, l-cystine, l-thyroxine, l-hydroxyproline etc.

Q. 12. How will you identify Proteins in the laboratory ?

The proteins can be identified by three groups of tests like *Colour reaction*, *Coagulation reaction* and *Precipitation reaction.*

I. Colour Reaction : It depends upon the reaction between some one or more of the constituent radicals or groups of the complex protein molecule and the chemical reagent or reagents used in any given test.

(a) *Biuret Test* : To 2 to 3 ml of the protein solution in a test tube, one or two drops of 1% copper sulphate solution and 10% caustic soda solution are added to it and a distinct violet colour appears. This reaction depends upon the peptide-linkage of protein molecule and presence of two $CONH_2$ groups or equivalent in the protein molecule.

(b) *Xanthoproteic Reaction* : To 2 to 3 ml of the protein solution, a few drops of concentrated nitric acid are added and a white precipitate appears. It is boiled for a minute and cooled and concentrated caustic soda is added till the reaction is alkaline. The yellow colour deepens into orange colour. The colour change is due to the presence of phenyl group (C_6H_5) in the protein molecule, with which nitric acid forms certain nitro-modification.

(c) *Millon's Reaction* : To 5 ml of the protein solution, few drops of Millon's reagent are added. A white precipitate forms which on heating becomes brick red precitate and collects itself into coagulum. The colour change is due to the presence of of hydroxy-phenyl group of amino-acid tyrosine in the protein molecule.

(c) *Adamkiewicz Reaction* : To 3 to 4 ml of protein solution, excess of glacial acetic acid is added and heated. Then it is cooled under tap water and few ml of concentrated sulphuric acid are allowed to flow down the side of the inclined test tube slowly. A reddish violet colour appears at the junction of the two liquids. The colour change is due to the reaction between gloxylic acid and the amino-acid typtophane present in the protein molecule.

II. Coagulation Reaction : This reaction occurs due to the colloidal nature of the protein and their high molecular weight.

(a) *Heat Coagulation Test* : 3 to 4 ml of the egg white solution is heated in a test tube and there will be the formation of coagulum, acidify with a few drops of 1% acetic acid, the precipitate separate out in the form of flocculi.

(b) *Heller's Nitric Acid Test*: Few ml. of concentrated solution run in into that test tube. A white ring formation of coagulated protein is formed at the junction of the two liquids.

III. Precipitation Reaction: This reaction occurs owing to the presence of basic character of the protein units.

(a) *Salts of Heavy metals*: 2 To 3 ml. of 1% mercuric chloride solution is added to the protein solution drop by drop. A heavy white precipitate is formed which dissolve in an excess of the reagent and reprecipitated on adding a few drops of dilute hydrochloric acid. The heavy precipitate is due to mercury proteinate formation.

(b) *Alkaloidal reagents in acid solution*:

(1) Equal volume of saturated solution of picric acid (Esbach's reagent) are added with protein solution. A yellow precipitate is formed.

(2) The protein solution is treated with 10% Trichloroacetic acid solution. A white paecipitate is formed.

(3) The protein solution is treated with 10% Trannic acid solution. A brownish precipitate is formed.

(4) When the protein solution is treated with 0·5 ml of Methylene blue solution, a bluish precipitate is formed.

Q. 13. What are Lipides? How are they Classified?

Lipide is one of the proximate principle of food stuffs, composed of fatty acids and glycerol. Chemically, the lipides are either esters of fatty acids or substances capable of forming such esters.

Classification of Lipides:

I. Simple Lipides: (Esters of fatty acids with various alcohols). They are usually further classified according to the nature of the alcohols, as follows:

(A) *Glycerides or Neutral lipides*: (Esters of fatty acids with glycerol)

(a) Fats: (Solid at 20°C)

   (1) Animal fats—Lard, Tallow, Butter, Human fat, etc.

   (2) Vegetable fats—Cocoa butter, Cocoanut oil, etc.

(b) Oils or Oleolipides: (Liquid at 20°C)

   (1) Marine Oils—Fish oil, Liver oil, Blubber oil, etc.

   (2) Vegetable oils—Rape oil, Olive oil, Castor oil, etc.

(B) *Waxes* : (Esters of fatty acids with long-chain aliphatic alcohols or with cyclic alcohols) e.g., Lanolin (wool wax), Bees wax, Spermaceti.

(C) *Sterols* : (Esters of higher fatty acids with alcohol containing phenanthrene nucleus)

(a) Zoosterol e.g. Cholesterol.

(b) Phytosterol e.g. Sitosterol.

(c) Mycosterol e g. Ergosterol.

II. **Conjugated or Compound Lipides** : (Esters of fatty acids with an alcohol plus other radicals). Some important members of this group are :

(A) Phospholipides or phosphatides or phospholipins—Lecithin, Cephalin, Sphingomyelin, Acetal phosphatides, etc.

(B) Glycolipides or cerebrosides or galactolipides—Phrenosine, Kerasine, Nervone, Hydroxynervone, etc.

(C) Others—Chromolipides, Aminolipides, Sulpholipides, etc.

III. **Derived Lipides** : (Intermediate products of hydrolysis of simple or compound lipides).

(A) *Fatty acids derived from natural products* : (a) Saturated fatty acids—Palmitic or Stearic acids, Myristic or Lignoceric acid etc. (b) Unsaturated fatty acids—Oleic acid, Linoleic acid, Arachidonic or Linolenic acid, etc.

(B) *Higher Monohydric alcohols* : (Compounds of high molecular weight but not glycerol). These may be classified as follows : (a) Aliphatic alcohols such as cetyl, stearyl and myricyl alcohols. (b) Alcohols containing the β-Ionone Ring : These include vitamin A, Kitol and Carotenols such as Cryptoxanthin, Lutein and Zeaxanthin.

(C) *Hydrocarbons* : (Compounds having no carboxyl or alcohol groups which cannot be saponified) : (a) Aliphatic Hydrocarbons—such as pentacosane and homologues to hentriacontane. (b) Carotenoids—such as α-, β-, and γ-carotene and lycopene. (c) Squalene (Unsaturated hydrocarbon)—such as in olive and shark liver oils.

IV. **Unclassified Lipides** :

(A) Vitamin E : It includes chroman derivatives, α-, β-, γ-, and δ- tocopherols.

(B) Vitamin K : It is the dervatives of 1, 4-naphthoquinone with long hydrocarbon side chains.

I. Simple Lipides.

These are esters of fatty acids with certain alcohols. They are usually further classified according to the nature of alcohols, as follows :

(A) **Glycerides or Neutral Lipides :** These are esters of fatty acids with glycerol. These include fats and oils.

(1) The **fats** are neutral esters of glycerol and fatty acids. The animal fats consist largely of mixed glycerides of Oleic, Palmitic and Stearic acid. Mutton fat contains more stearic acid and less oleic acid than pork fat. Human fats contain a high percentage of oleic acid. Butter fat consists largely of glycerides of palmitic and oleic acids, with small amounts of stearic acid and of the lower fatty acids such as butyric and caproic acids.

(2) The **oils** are of Marine oils such as fish oil, liver oil, blubber oil etc. and Vegetable oils such as rape oil, olive oil and castor oil etc.

(B) **Waxes :** These are esters of fatty acids with long chain aliphatic alcohols. The examples of waxes are spermaceti, containing chiefly the palmitate of cetyl alcohol and beeswax, consisting mainly the paimitate of myricyl alcohol. They are saponified with greater difficulty and are not acted upon by lipase.

(C) **Sterols :** These are esters of higher fatty acids with alcohol containing phenanthrene nucleus. These are different types such as Zoosterol e.g., cholesterol, Phytosterol e.g., sitosterol, Mýcosterol e.g., ergosterol and stigmasterol.

II. Conjugated or Compound Lipides.

These are esters of fatty acids which on hydrolysis, yield other substances in addition to fatty acids and an alcohol. Some important members of this group are :

(A) **Phospholipides or Phosphatides or Phospholipins :**

Lipides which, on hydrolysis, yield fatty acids, phosphoric acid, sometimes, but not always, glycerol and a nitrogenous base. These are subdivided into the following groups :

(a) **Lecithins :** Lipides containing glycerol saturated and unsaturated fatty acid residues, phosphoric acid and the nitrogenous base choline.

(b) **Cephalins :** Lipides which yield on hydrolysis, form glycerol, saturated and unsaturated fatty acids residues, phosphoric acid and either the base ethanolamine (colamine) or the aminoacid serine.

(c) **Sphingomyelins :** Lipides which yield on hydrolysis, form a single fatty-acid molecule, phosphoric acid, choline and a nitrogenous base sphingosine but no glycerol.

(d) **Acetal Phosphatides :** They are made up of glycerol, phosphoric acid, choline and acetals of fatty aldehydes combined with cholamine glycerophosphate.

(B) **Glycolipides or Cerebrosides or Galactolipides** : Lipides which, on hydrolysis, yield one fatty acid, a nitrogenous base spingosine, a molecule of carbohydrate (glucose or galactose), but no phosphoric acid or glycerol.

(a) *Kerasine* (cerasine)—containing lignoceric acid.

(b) *Phrenosine*—containing cerebronic acid.

(c) *Nervone and Oxynervone*—containing nervonic and oxynervonic acid respectively.

(C) **Sulpholipides** : Lipides which, on hydrolysis, yield sphingosine, galactose, cerebronic acid, sulfuric acid and potassium.

III. Derived Lipides.

These are intermediate products of hydrolysis of simple or compound lipides which still retain the properties of this class of compound. They are as follows :

(A) **Fatty acids derived from Natural Products** :

(a) **Saturated fatty acids** : Its physical properties depend upon their molecular weights. The common straight-chain saturated fatty acids found in nature as constituents of lipide molecules are Palmitic, Stearic, Myristic Lignoleric acid which contain no double bond in the molecule.

(b) **Unsaturated fatty acids** : These are characterised by the presence of one or more double bonds in the molecule. The most common straight-chain unsaturated fatty acid found in nature is the monoethenoid acid, oleic acid, diethenoid acid, linoleic acid, found in both animal and plant fats, triethenoid acid, linolenic acid found largely in vegetable fats and the phosphatide fractions of many animal tissues, particularly in liver and in suprarenal phospholipides.

(B) **Higher Monohydric Alcohols** : These are cetyl, stearyl and myricyl alcohols. (b) *Aliphatic alcohols*—These are cetyl, stearyl and myricyl alcohols. (b) *Alcohols containing the β-Ionone Ring*—These include Vitamin A, kitol and casotenols such as cryptoxanthin, lutein and zeaxanthin.

(C) **Hydrocarbons** : These compounds having no carboxyl or alcohol groups which cannot be saponified. These may be classified as follows : (a) *Aliphatic Hydrocarbons*—These are pentacosane and homologues to hentriacontane. (b) *Carotenoinds*—These are α—, β—and γ,—carotene and lycopene. (c) *Squalene*—These are unsaturated hydrocarbons found in olive and shark liver oils.

IV. Unclassified Lipides.

(a) **Vitamin E** : It includes chroman derivatives, α-, β- γ-, and δ-tocopherols.

(b) **Vitamin K** : It is the derivative of 1, 4-naphthoquinone with long hydrocarbon side chains.

Q. 14. What are Carbohydrates ? How are they classified ?

Carbohydrates are one of the proximate principles of food stuffs composed of carbon, hydrogen and oxygen ; the hydrogen and oxygen being in the same proportion as they are in water except Rhamnose, $C_6H_{12}O_5$. Chemically, they are polyhydroxyaldehydes and polyhydroxyketones and their condensation products. The primary alcohols yield aldehydes and the sugars are known as aldoses (Dextrose, Galactose, Mannose etc.) and similarly the secondary alcohols yield ketoses (Levulse).

Classification of Carbohydrates.

I. **Simple Carbohydrates** : These are usually classified according to the number of simple carbohydrate groups.

(A) **Monosaccharides** : (Containing only simple sugar unit and capable of reducing alkaline copper solution. They cannot be hydrolysed into simipler substances and are further classified according to the length of the carbon chain).

(a) *Monose*—with single carbon atom, CH_2O.

(b) *Diose*—with two carbon atoms, $C_2H_4O_2$.

(c) *Triose*—with three carbon atoms, $C_3H_6O_3$.

(d) *Tetrose*—with four carbon atoms, $C_4H_8O_4$.

(e) *Pentoses*—with five carbon atoms, $C_5H_{10}O_5$ e.g., Ribose, xylose, arabinose, rhamnose (methyl-pentose) $C_6H_{12}O_5$, deoxyribose $C_5H_{10}O_4$ etc.

(f) *Hexoses*—with six carbon atoms, $C_6H_{12}O_6$ e.g., Glucose, levulose or fructose, galactose, mannose etc.

(B) **Oligosaccharides** : (Contanining more than one monosaccharide isomaltose, cellobiose etc.

(a) *Disaccharides* ($C_{12}H_{22}O_{11}$). They give two molecules of simple sugars on hydrolysis, such as maltose, lactose, sucrose, gentiobiose, isomaltose, cellobiose etc.

(b) *Trisaccharides* ($C_{18}H_{32}O_{16}$). They give three molecules of simple sugars on hydrolysis, such as Raffinose.

(c) *Tetrasaccharides* ($C_{24}H_{42}O_{21}$). They give four molecules of simple sugars on hydrolysis, such as Stachyose.

(d) *Polysaccharides* $(C_6H_{10}O_5)_n$. Where *n* represents the number of simple sugar groups present. They give many molecules of simple sugars on hydrolysis. They fall into two groups—starch group and cellulose group.

(1) Starch group—starch, dextrin, glycogen, inulin etc.

(2) Cellulose group.

1. Cellulose—In consists of a large number of β-glucose units joined together by 1, 4-glycoside bonds.

2. Hemicelluloses—They may be hydrolysed upon boiling with dilute mineral acids and upon hydrolysis it may yield pentoses or hexoses or both, together with uronic acids. (i) Pentosans—Gum arabic. (ii) Hexosans—Galactans, agar-agar, dextrans, levans etc. (iii) Hexo-pentosans—Pectin.

II. **Conjugated Carbohydrates :** In these compounds, a simple sugar molecule remain conjugated with another non-sugar prosthetic group. The examples are the glycoprotein, chondroprotein, ovomucoid, glucolipide etc.

I. Simple Carbohydrates.

These are usually classified according to the number of simple carbohydrate groups.

A. **Monosaccharides :** They contain only single sugar unit and capable of reducing alkaline copper solution. Monosaccharides are further classified into two ways : According to the number of carbon atoms present in the molecule, viz., Monose, Diose, Triose, Tetrose, Pentose, Hexoses etc, containing 1, 2, 3, 4, 5, 6 carbon atoms respectively. (2) According to the nature of reducing group containing, viz, *Aldoses* containing aldehyde group e.g. glucose mannose, etc. or *Ketoses* containing ketone group e.g., fructose.

(1) **Pentoses :** Pentoses are usually defined as sugars containing five carbon atoms in the molecule except rhamnose, $C_6H_{12}O_5$, a methyl pentose. These are an important constituents of the diet of harbivorous animal. Their role in human nutrition is not well established. Two pentoses are common such as Ribose, which is a consituent of adenylic acid, guanylic acid, inosinic acid etc. and Arabinose which is commonly found in gum arabic as l-arabopyranose.

(2) **Hexoses :** The hexoses are monosaccharides containing a chain of six carbon atoms in the molecule. The most important hexoses are glucose, fructose, galactose and mannose. Of these, fructose is a ketohexose and in the others are aldohexoses.

(a) **Glucose :** It is an aldose, dextro-rotatory and found in grapes. It is found in nature in free form, in the form of disaccharides such as maltose, cane sugar etc.. in the from of polysaccharides such as starch, glycogen etc. and in combination with proteins forming conjugated proteins such as glycoproteins.

(b) **Fructose** : It is a keto-hexoses, as lævorotatory and present in honey and nearly in all sweet fruits. It converts into glucose rapidly in the human liver. Fructose is soluble in hot absolute alcohol and plays important role in carbohydrate metabolism.

(c) **Galactose** : It is an aldohexose, found in the milk and so it is known as milk sugar. It is also present in combination with lipides forming conjugated lipides as cerebrosides or glactolipides.

(d) **Mannose** : It is an aldohexose and found as a constituents of egg-albumin. It is also present in the ivory nuts as a polysaccharide.

B. **Disaccharides** : The disaccharide may be regarded as glycoside in which both components of the molecule are sugars. The common disaccharides have the general formula $C_{12}H_{22}O_{11}$, and yield hexoses from hydrolysis with the elimination of the molecule of water. The most important disaccharides are the maltose, lactose, sucrose etc.

(a) **Maltose** : Maltose or malt sugar is formed in the hydrolysis of starch through the action of enzymes. It is composed of two glucose units. Maltose is strongly dextrorotatory, shows mutarotation, reduces metalic ions in alkaline solutions and is fermentable by yeast after being converted to glucose by the enzyme maltose of the yeast. With phenylhydrazine, maltose form an osazone known as maltosazone.

(b) **Lactose** : Lactose or malt sugar occurs only in milk but it is also found in the urine of women during the period of lactation. It is a reducing disaccharide, dextrorotatory, exhibits mutarotation in solution and forms an osazone with phenylhydrazine known as lactosazone. On hydrolysis, lactose yields glucose and galactose.

(c) **Sucrose** : Sucrose or cane sugar is found particularly in the sugar cane, sugar beet and certain palms. It is dextro-rotatory, does not form osazones and does not show mutarotation in solution and therefore it is not a reducing sugar.

C. **Polysaccharides** : These are complex carbohydrates of high molecular weight, either insoluble in water or, when soluble, forming colloidal solution. The most important common polysaccharides are starch, dextrine, glycogen, inulin, cellulose.

(a) **Starch** : Is is widely distributed throughout the vegetable kingdom occuring in grains, fruits and tubers. It is insoluble in cold water due to the presence of outer cellulose layer around the granule. The chief constituents of starch are amylose and amylopectin, which usually exists in a proportion of about 1 : 3 in the granules. On hydrolysis with acids, starch breaks down into glucose. It gives blue colour with iodine. It has got no reducing power and is tasteless.

(b) **Dextrins :** The dextrins are found as intermediate products in the course of hydrolysis of starch to glucose or maltose by acids or enzymes. They are colloidal in nature but of a lower degree of molecular complexity. The dextrins may be hydrolysed by dilute acids to form glucose and by amylases to form maltose. Various dextrins give different colours with iodine depending upon their molecular complexity. The higher dextrins (amylodextrins) give a blue or purple colour, intermediate dextrins (erythrodextrins) give a red colour and the lower dextrins (achroodextrins) may give no colour at all.

(c) **Glycogen :** It is an animal starch remains stored in the liver and muscles of animal body. It is also found in non-green plants such as in yeast and fungi. Glycogen is soluble in water, makes an opalescent solution and gives reddish colour with iodine.

(d) **Inulin :** It is obtained as a white, odourless, tasteless powder from the tubers of artichoke, dahlia. It is very slightly soluble in cold water, quite easily soluble in hot water and practically insoluble in cold alcohol. Inulin gives a negative reaction with iodine solution and is a polymerised form of fructofuranose. It is laevorotatory and upon hydrolysis by the enzyme inulase, it yields the monosaccharide fructose which readily reduces Benedict's solution.

(e) **Cellulose :** It is a stable insoluble compound, found in a large portion of the cell walls of plants. Cellulose, by hydrolysis yields glucose. It adds "bulk" to the intestinal contents, stimulate peristalsis and thereby help in the formation and expulsion of faeces.

(f) **Hemi-cellulose :** It may by hydrolysed upon boiling with dilute mineral acids. They are not readily digested by amylases. Hemicellulose upon hydrolysis, may yield pentoses or hexoses or both, together with uronic acids. The most common hemicellulose are Pentosans such as gum-arabic, Hexosans such as galactans, agar-agar, dextrans etc. and Hexopentosans such as pectin etc.

II. **Conjugated Carbohydrates :** In these compounds, a single sugar molecule remains conjugated with another non-sugar prosthetic group. The most important conjugated carbohydrates are glycoprotein, chondroproteins, ovomucoid, glucolipide etc.

CHAPTER THREE

ALIMENTATION

Introduction : Alimentation or digestion is a plysico-chemical process by means of which an insoluble and complex food matters are converted into soluble and simple one by the activation of different types of digestive juices that are liberated from different types of digestive glands which are located in the different parts of the gastro-intestinal tract. The organs cnncerned are known as digestive organs and the process concerned is known as digestive system.

The digestive system comprise of alimentary tract and digestive glands. The alimentary tract consists of *mouth* guarded by lips and teeth, *tongue, pharynx, oesophagus, stomach* comprising of fundus, body and pylorus, *small intestine* comprising of duodenum, jejunum and ileum, *large intestine* comprising of ascending colon, transverse colon and descending colon, *rectum* and *analcanal.*

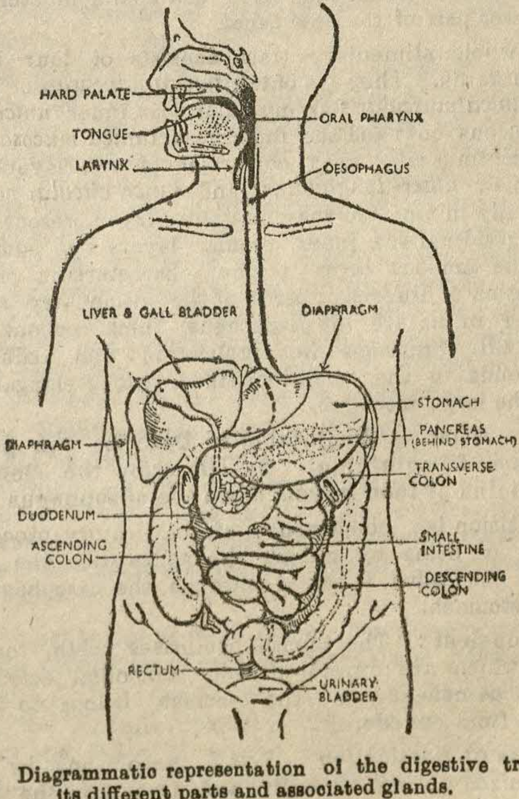


Fig. 12. Diagrammatic representation of the digestive tract showing its different parts and associated glands.

The digestive glands are the *salivary glands* comprising paired parotid glands, sub-lingual glands and sub-maxillary of sub-mandibular glands, *gastric glands* present in the stomach, *pancreatic glands*, present in the pancreas, *hepatc glands* present in the liver and *intestinal glands* present in the small intestine. The salivary glands produce saliva, gastric glands produce gastric juice, pancratic glands produce pancreatic juice, hepatic glands liberate bile and intestinal glands secrete succus entericus.

There are a number of sphincters present in different junctional places of the alimentary tract known as cardiac sphincters, pyloric sphincters, ileo-colic sphincters and anal sphincters. Cardiac sphincter is present at the junction of oesophagus and stomach, pyloric sphincter is situated at the junction of pyloric part of the stomach and duodenum, ileo-colic sphincter is present at the junction of ileum and colon and anal sphincter is situated at the lower part of the anal canal.

The whole alimentary tract consists of four layers from outside inwards. They are outer *tunica adventita* or serous coat, middle *tunica muscularis* or muscular coat, inner *tunica submucosa* or sub-mucous coat and the innermost *tunica mucosa* or mucous coat. The muscular coat comprises of two layers mainly in general i.e., *outer longitudinal* and *inner circular muscle layers* but specially in stomach there is a third layer present in between outer longitudinal and inner circular layers i.e. *middle oblique layer*. The mucous layer is the characteristic part for the identification of different parts of the alimentary tract. It is corrugated in nature in oesophagus, thick mucous fold in the stomach, villi formation i.e. duplication and reduplication of mucous folds in the small intestine and long elongated mucous folds in the large intestine.

Q. 1. What is Deglutition? Describe the process and mechanism of Deglutition. Or, Describe the mechanism by which a bolus of food travels down the oesophagus.

Deglutition is a phenomenon of masticatory process and the formation of bolus by mixing the saliva with the masticated food and the bolus is passed through the oesophagus and rest into the stomach.

Development : The mouth comprises teeth, tongue, facial muscles which are developed from stomodial ectoderm. The pharynx, oesophagus and the stomach belong to foregut, are developed from endoderm.

Process of Mastication : It is a phenomenon by which the food is mixed up with the saliva and ground by the teeth, aided by the cheeks, lips and tongue. This process comprises of the following factors :

(a) **Process of Tearing :** It is effected by the different types of feeth. The *Incisor teeth* helps in the process of incision over the food stuffs. The *Canine teeth* helps in the process of cutting of the food stuffs into smaller particles. The *Pre-molar teeth* helps in the conversion of small particles of food into minute particles. The *Molar teeth* helps in the process of grinding of the minute food particles.

(b) **Process of Jaw Movement** : It is effected by the process of elevation and depression, protrusion and retraction together with side to side motions.

Process of Deglutition : The food after mastication i.e., the masticated food when mixed up with saliva forms bolus and that is carried to the stomach by a complex series of co ordinated movements involving the muscles of the mouth, pharynx and oesophagus.

(a) **Different Phases of Deglutition** : *Magendie* divides the act swallowing into three stages :

(1) **First Stage** : The food when masticated is collected as a bolus on the dorsum of the tongue which lies infront of isthmus of fauces. Due to the contraction of mylohyoid muscle, the tongue pressed against the hard palate carrying the masticated food as an arc of a circle. Then the tongue is drawn backwards by three sets of muscles known as hypoglossi, the glosso-palatini and the styloglossi. In this stage, 20 ml. of water is produced in the posterior part of the mouth, pharynx and upper part of the oesophagus by the muscular movements of the mylohyoids. (2) **Second Stage** : In this stage, the food enters into the pharynx and constrictor muscles contract which helps the food to pass into the oesophagus. (3) **Third Stage** : It involves the passage of the food down the oesophagus.

(b) **Time Relationships during Deglutition** : The total time period during deglutition requires 7 sec. time. The initiation of the swallowing act to reach the upper opening of the oesophagus requires about 1 sec. time. The cervical portion of the oesophagus takes 1 sec. time, upper thoracic portion takes 2 sec. time and the lower thoracic portion of the oesophagus requires 3 sec. time.

Nervous Mechanism of Deglutition : The nervous mechanism of deglutition comprises of centres, nerves and reflexes.

(a) **Centres** : The centre for the act of the deglutition is situated in the medulla oblongata and can be considered as consisting of the chain of centres, stimulation of one of which involves the firing off all the others in orderly sequence.

(b) **Nerves** : The nerves comprising deglutition are of afferent and efferent nerves. (2) *Afferent Nerves* : These are : (i) Branches of the trigeminal nerve. (ii) Branches of the glossopharyngeal nerve. (iii) Pharyngeal and Superior laryngeal branch of vagus. These branches help in the innervation of the mucosa in the regions about the entrance to the pharynx. (2) *Efferent Nerves*: These are; (i) Hypoglossal nerve to the lingual muscles. (ii) Third division of the Trigeminal nerve to the mylohyoid muscle. (iii) Pharyngeal branches of the glosso-pharyngeal nerve. (iv) Pharyngeal and Oesophageal branches of the vagus to the muscles of the pharynx and oesophagus.

(c) **Reflexes**: The reflexes concerning deglutition are of complete reflex act and the chain reflex. (1) **Complete Reflex Act**: Deglutition is a typical reflex act. Swallowing reflexes are readily elicited in the decerebrated animal, when water or dilute alcohol is placed in the mouth. When we swallow voluntarily, we supply the necessary initial stimulus, either by touching fauces with the tongue or by forcing saliva or food into this fauces. Both contraction and relaxation of the muscles of the upper division of the swallowing apparatus including the soft palate, involve the activity of the cerebral cortex. The moment of the food passes the palatine arches the process becomes involuntary i.e. independent of the cerebral cortex. (2) **Chain Reflex**: This reflex is done by the successive process of deglutition. When one process is finished, the successive processes are continued by means of a chain of reflexes which is known as *chain reflex*.

Q. 2. How Proteins are digested in the alimentary tract?

Digestion is a physico-chemical process by means of which an insoluble and complex food matter is converted into soluble and simple one by the activation of different types of digestive enzymes which are present in various types of digestive juices that are liberated from different types of digestive glands which are located in the different parts of the gastro-intestinal tract and the food stuffs that are digested, are ready to be absorbed. The digestion of protein is the conversion of different types of protein food stuffs into simple amino-acids by the activation of different types of protein splitting enzymes such as pepsin, trypsin, erepsin etc.

I. Enzymes Concerned in Protein digestion.

(a) In the Gastric juice—Inactive pepsinogen.
(b) In the Pancreatic juice—Inactive trypsinogen.
(c) In the Intestinal juice or Succus entericus
—Active erepsin.

II. Mode of Action of different Proteolytic enzymes on Protein food stuffs.

(a) **Action of Inactive Pepsinogen**; It is liberated from the peptic cells of the stomach. It is converted into active pepsin with the help of hydrochloric acid at an optimum pH 2·0. The acid metaprotein forms with the combination of protein and hydrochloric acid which is liberated from the oxyntic cell of the stomach. This active pepsin acts upon acid metaprotein and digests potein upto peptone stages. The stages of digestion are Acid metaprotein→Primary proteoses→Secondary proteoses→ Peptone.

(b) **Action of Inactive Trypsinogen :** It is secreted from the pancreatic cells. It becomes active by the action of enterokinase which is present in the insestinal juice and in alkaline media, it froms active trypsin. The alkali mixes with protein, forms alkali metaprotein. This active trypsin acts upon alkali metaprotein and breaks down upto polypeptide stage. The stages of breakdown of alkali metaprotein by active trypsin are Alkali metaprotein→Primary proteoses→Secondary proteoses→ Peptones→Polypeptides. The active trypsin also acts upon peptone in acid side and breaks down into polypeptide stage.

(c) **Action of Active Erepsin :** It is a proteotytic enzyme liberated in active form from the intestinal glands. It acts upon polypeptides in alkaline media at optimum pH about 8·0 and breaks down upto amino-acid stage. The stages of break down of polypeptides by active erepsin are Polypeptides→Dipeptides→ Amino-acids. The active erepsin also acts upon polypeptide in acid side and converts completely into amino-acids.

III. Schematic Representation of Protein Digestion :

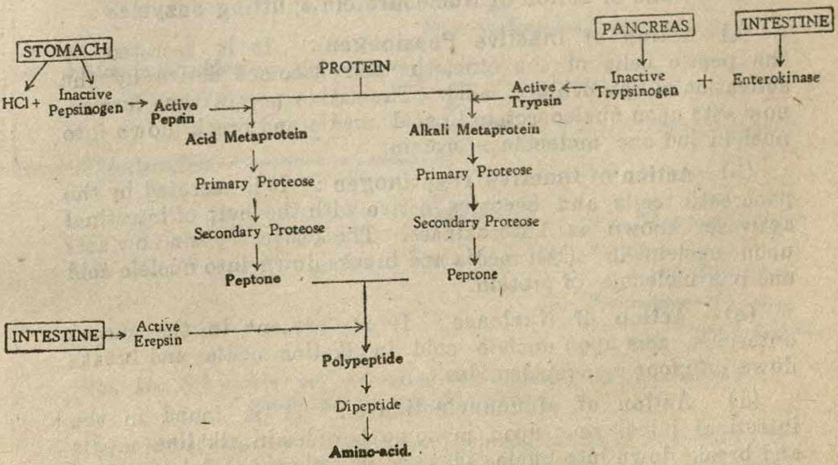


Fig. 13. Schematic representation of the digestion of protein showing its stages of brerkdown.

Therefore, the end products of natural protein digestion are the amino-acids finally which are produced by the action of different types of protein splitting enzymes.

Q. 3. What is Nucleo-protein ? How it is digested ?

The nucleo-protein is a conjugated protein, contains simple protein like protamines or histones and the non-protein prosthetic group is the nucleic acid. It is found in the nucleus and cytoplasm of the vegetative cells of the plant body and the cell nucleus of the fish, meat and egg of animals and it is also present in nucleus of the body cell.

The digestion of nucleo-protein is the conversion of nucleo-protein food stuffs into phosphoric acid, a pentose carbohydrate called Ribose and the nitrogenous bases like purine and pyrimidine by the activation of different types of nucleo-protein splitting enzymes that are present in the different digestive juices.

I. Enzymes Concerned in Nucleoprotein digestion :

(a) In the Gastric juice—Inactive pepsinogen.

(b) In the Pancreatic juice—Inactive trypsinogen.

(c) In the Intestinal juice—Nuclease, Mononucleotidase, Nucleosidase etc.

(b) Specific tissue enzymes—Ribonuclease, Disoxyribonuclease etc.

II. Mode of action of Nucleoprotein splitting enzymes :

(a) **Action of Inactive Pepsinogen :** It is secreted by the peptic cells of the stomach and becomes active by the activation of hydrochloric acid. The active pepsin thus formed, now acts upon nucleoprotein in acid media and breaks down into nuclein and one molecule of protein.

(b) **Action of Inactive Trypsinogen :** It is secreted by the pancreatic cells and becomes active with the help of intestinal activator known as enterokinase. The active trypsin now acts upon nuclein in alkali media and breaks down into nucleic acid and one molecule of protein.

(c) **Action of Nuclease :** It is present in the succus entericus, acts upon nucleic acid in alkaline media and breaks down into four mononucleotides.

(d) **Action of Mononucleotidase :** It is found in the intestinal juice, acts upon mono-nucleotides in alkaline media and breaks down into nucleosides and phosphoric acid.

(e) **Action of Nucleosidase :** It is present in the intestinal juice, acts upon nucleosides in alkaline media and breaks down into pentose carbohydrate and nitrogenous bases like purine base comprising adenine and guanine and pyrimidine base comprising thymine and cytosine.

(f) **Action of specific tissue enzymes:** The specific tissue enzymes are ribonuclease and desoxyribonuclease which are found in pancreas and other animal tissues, in yeasts and certain bacteria. These specific tissue enzymes break the respective nucleic acid molecules into smaller groups like oligonucleotides and tetranucleotides.

Schematic Representation of Nucleo-protein Digestion:

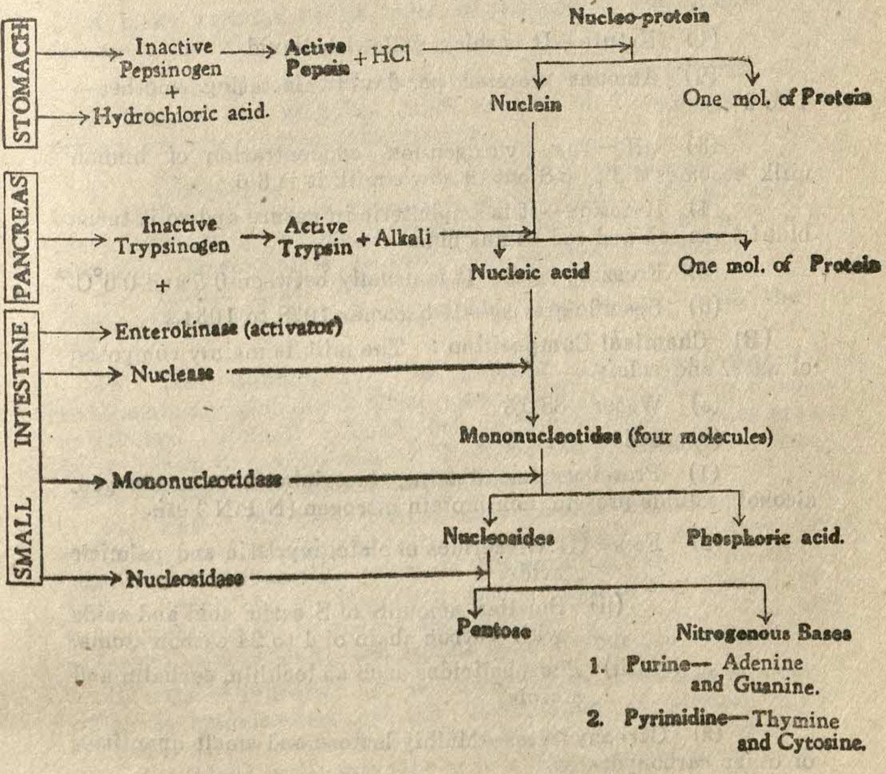


Fig. 14. Schematic representation of digestion of Nucleo-protein showing its stages of breakdown.

Therefore, the end products of nucleo-protein digestion are the phosphoric acid, pentose carbohydrate and the nitrogenous bases like purine base comprising adenine and guanine and the pyrimide base comprising thymine and cytosine.

Q. 4. What is milk ? Write down the composition of milk. What do you mean by humanisation of cow's milk ?

Milk is the indespensable food of the new born and the principal food stuffs of the growing child. It is an ideal complete food of the human being, secreted from the mammary glands of the female individuals after first three days of the birth of the bady. It is thick in consistency, yellowish in colour and very rich in proteins and salts.

Composition of Milk :

(A) **Physical Properties :**

(1) Nature—It is thick, yellowish liquid.

(2) Amount secreted per day in lactating mother—1 to 3 liters.

(3) pH—The hydrogen-ion concentration of human milk becomes 6·3 to 6·8 but in cow's milk it is 6·6.

(4) Reaction—It is amphoteric in nature and so it turns blue litmus red and red litmus blue.

(5) Freezing point—It is usually between-0 5 and-0·6°C.

(6) Specific gravity—It becomes 1028 to 1034.

(B) **Chemical Composition :** The milk is mainly composed of water and solids.

(a) Water—88·5%

(b) Solids—11·5%

(1) Proteins—Lactalbmin, lactglobulin, caseinogen, alcohol, soluble protein, non-protein nitrogen (N.P.N.) etc.

(2) Fats—(i) Glycerides of oleic, myristic and palmitic acids.

(ii) Smaller amounts of Stearic acid and acids with carbon chain of 4 to 24 carbon atoms.

(iii) Phospholipides such as lecithin, cephalin and sterols.

(3) Carbohydrates—Mainly lactose and small quantities of other carbohydrates.

(4) Inorganic Salts—Potassium, Calcium, Sodium, Phosphate and Chloride with small quantities of citrate and lactate.

(5) Vitamins—Vitamin A, B_1, B_2, Niacin, C and D etc.

(6) Other minute constituents—Antibodies and certain number of enzymes such as catalase, oxidase, reductase, etc.

Comparison between Human milk and Cow's milk :

The main difference of the different constituents of human milk and cow's milk are given in a tabular form below :

Mammary Secretions	Water%	Protein gm. %	Fat gm. %	Carbohydrate gm. %	Salts gm. %	Vitamins
Human milk	88·5	1·50	4·0	6·8	0·2	A,D, B_1, B_2, C
Cow's milk	87·1	3·5	3·5	4·8	0·7	A, C, B_2, D

A short account of the chief constituents of human milk is discussed below :

(1) **Proteins** : The principal proteins in milk are caseinogen, lact albumin, lact globulin, small amount of alcohol, soluble protein and some non-protein nitrogen.

(2) **Caseinogen** : It is a phosphoprotein and it contains all the essential amino-acids necessary for the growth of the tissues excepting cystine which is present in large amount in lact albumin. Caseinogen is converted into paracasein by the rennin in the gastric juice. The normal ratio of lact albumin and caseinogen is 1 : 2 in human being, but in cow's milk the ratio is 6 : 4.

(3) **Lact albumin and lact globulin** : Thy are identical to albumin and globulin of blood plasma which include maternal antibodies. Globulin is found only in minute traces. They are derived from the amino-acids of the blood and synthesized by the mammary gland. They are coagulated in heating.

(4) **Fat** : The fat is present in emulsified form in milk and is made up of mainly by the glycerides of oleic, myristic and palmitic acid and smaller amounts of stearic acid and acids with carbon chains of 4 to 24 carbon atoms. The milk is white due to the presence of emulsified fat globules. Phospholipides such as lecithin and cephalin and sterols are also found in the milk.

(5) **Carbohydrate** : It is a disaccharide, known as lactose, which is manufactured by the combination of glucose and galactose within the alveoli of the mammary gland. Glucose from the blood will enter the alveoli where part of the glucose will be converted into galactose and glucose and galactose will combine together to form lactose.

(6) **Inorganic Salts** : The main cations in milk are potassium, calcium and sodium and the main anions are phosphate and chloride, with small quantities of citrate and lactate.

(7) **Vitamins :** Vitamins A, C and B_1 and B_2 are found in sufficient quantities to satisfy the needs of the child but there is not enough vitamin D present in the milk.

Humanisation of Cow's milk.

Equal quantity of water is added to the milk protein concentration in the cow's milk will be equal to that of human milk. By adding water, the concentration of carbohydrate and fat will be diminished and so, fat in the form of cream and carbohydrate in the form of cane sugar or lactose are added to the milk.

Q. 5. Describe the Digestion of Milk.

Milk is the ideal food for the newborn that contains caesinogen, lact albumin, lact globulin, fat and carbohydrate food stuffs.

The digestion of milk is the conversion of milk protein (caesinogen, lact albumin and lact globulin etc.) into amino-acids, fats into fatty acids and glycerol and carbohydrates into glucose and galactose by the activation of milk curdling enzymes, fat splitting enzymes and carbohydrate splitting enzymes.

I. Enzymes Concerned in Milk Digestion :

(a) *Caesinogen of Milk :*

(1) In the Stomach—Gastric Rennin, Cathepsin.

(2) In the Pancreas—Chymotrypsin.

(b) *Lact albumin and Lact globulin :*

(1) In the Stomach—Active Pepsin and Hydrochloric acid.

(2) In the Pancreas—Active Trypsin.

(3) In the Small Intestine—Active Erepsin.

(c) *Fat (Phospholipide) :*

(1) In the Stomach—Gastric lipase.

(2) In the Pancreas—Pancreatic lipase.

(3) In the Small Intestine—Intestinal lipase.

(d) *Carbohydrate (Lactose) :*

In the Small Intestine—Lactase.

II. Mechanism of Digestion of Milk :

(A) **Digestion of Milk Protein :** The principal proteins in milk are mainly caseinogen, lact albumin and lact globulin and their process of digestion are discussed individually.

(a) **Digestion of Caseinogen :** The milk protein caseinogen is acted on by the milk curdling enzyme such as either gastric rennin or chymotrypsin and is converted into proteose like substance such as whey protein and soluble casein which will combine with ionised calcium to form insoluble calcium caseinate that is 'curd'. The curd is a protein and it is acted by active pepsin and hydrochloric acid and breaks down upto peptone stage. This peptone will be converted into polypeptide stage by the activation of active trypsin of the pancreas. This polypeptide will be converted finally into amino-acids by the action of active erepsin of the succus entericus. The stages of digestion of Caseinogen by milk curdling enzymes is summarised below :

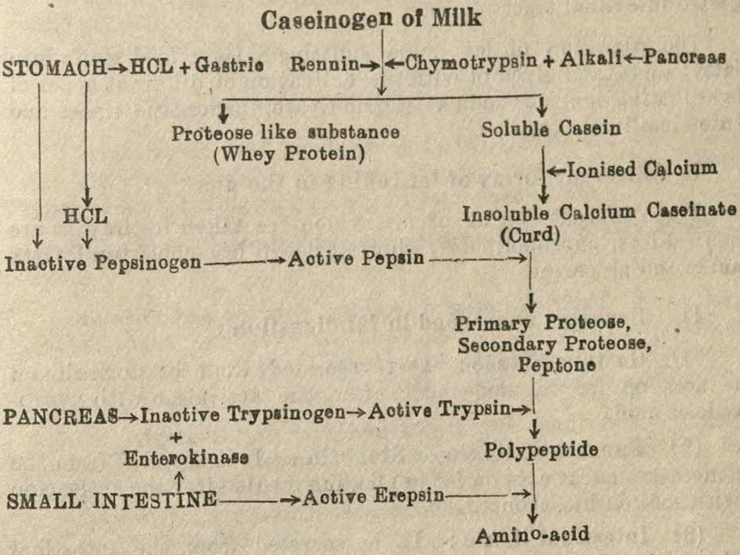

Caseinogen of Milk
STOMACH→HCL + Gastric Rennin→
←Chymotrypsin + Alkali←Pancreas
Proteose like substance (Whey Protein)
Soluble Casein
←Ionised Calcium
Insoluble Calcium Caseinate (Curd)
HCL
Inactive Pepsinogen→Active Pepsin→
Primary Proteose, Secondary Proteose, Peptone
PANCREAS→Inactive Trypsinogen→Active Trypsin→
+
Enterokinase
Polypeptide
SMALL INTESTINE→Active Erepsin→
Amino-acid

Fig. 15. Schematic representation of digestion of Caseinogen of Milk.

(b) Digestion of Lact Albumin and Lact Globulin :

The lact albumin and lact globulin are digested by active pepsin and hydrochloric acid in the stomach and breaks down into primary proteose, secondary proteose and peptone. This peptone will be acted on by active trypsin in the pancreas and will be converted into polypeptides. This polypeptide breaks down into amino-acids by the action of active erepsin in the small intestine.

(B) **Digestion of Fat :** The fat in milk is mainly phospholipide which is digested by the gastric lipase, pancreatic lipase and intestinal lipase and will be converted into fatty acids and glycerol.

(C) **Digestion of Carbohydrate :** The carbohydrate in milk is lactose which is acted on by an enzyme lactase of the succus entericus and is converted into glucose and galactose.

Q. 6. How Fats are digested in the alimentary tract ?

Digestion is a physico-chemical process by means of which an insoluble and complex food matters are converted into soluble and simple one with the activation of different types of enzymes that are present in the digestive juices which are secreted from the digestive glands that are lodged in the different parts of the gastro-intestinal tract.

The digestion of fat is the splitting of fatty food stuffs into fatty acids and glycerol with the activation of different types of fat splitting enzymes such as gastric lipase, pancreatic lipase and intestinal lipase etc.

I. Different forms of fat taking in the diet :

The different forms of fat which are taken in the diet are neutral fats, phospholipides, cholesterides, free-cholesterol, fatty acids and glycerine.

II. Enzymes concerned in fat digestion :

(1) **Gastric lipase :** It is secreted from the stomach and it acts on fat in acid media after the activation with hydrochloric acid.

(2) **Pancreatic lipase or Steapsin :** It is secreted from the pancreas and it acts on fat in alkaline media after the activation with sodium bicarbonate.

(3) **Intestinal lipase :** It is secreted from the intestinal glands such as crypts of Leiberkuhn and acts on fat in alkaline media.

III. Mechanism of Fat digestion :

(a) **In the Stomach :** Gastric lipase is a distinct lipolytic enzyme present in the gastric juice. Gastric lipase acts on neutral fats in slightly acid medium and breaks down into one molecule of glycerol and three molecules of fatty acids.

(b) **In the Pancreas :** Pancreatic lipase is present in the pancreatic juice. It acts best in a slightly alkaline medium at pH 8 the activation of Pancreatic lipase on fat, it breaks down into fatty acids and glycerol.

(c) **In the Small Intestine :** The main digestion of fat undoubtedly occurs in the small intestine. Intestinal lipase is secreted from the intestinal gland and completely hydrolyses in the intestine to one molcoule of glycerol and three molecules of fatty acid before absorption.

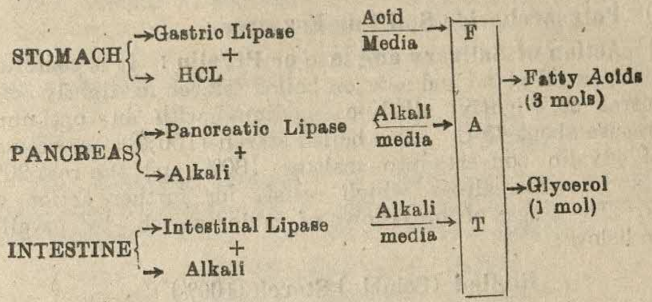


Fig. 16. Schematic representation of Digestion of Fat.

Therefore, the end products of fat digestion are fatty acids and glycerol which are produced by the activation of different types of fat splitting enzymes upon fatty food stuffs.

Q. 7. How Carbohydrates are digested in the alimentary tract ?

Digestion is a physico-chemical process by means of which an insoluble and complex food matters are converted into soluble and simple one with the activation of different types of carbohydrate splitting enzymes which are present in the digestive juices.

The digestion of carbohydrate is the conversion of polysaccharides and disaccharides into monosaccharides by the activation of different types of carbohydrate splitting enzymes such as salivary amylase, pancreatic amylase, intestinal amylase maltase, lactase etc.

I. Different forms of Carbohydrates present in the diet :

(a) Polysaccharides—chiefly starch and cellulose.

(b) Disaccharides—chiefly lactose, maltose, sucrose etc.

(c) Monosaccharides—chiefly glucose and fructose.

II. Enzymes Concerned in Carbohydrate Digestion.

(a) In the Saliva— Salivary amylase or Ptyalin and traces of maltase.

(b) In the Gastric juice—Maltase if present.

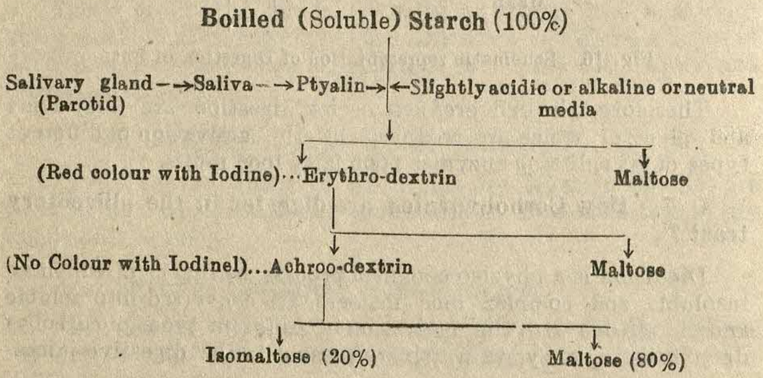
(c) In the Pancreatic juice—Pancreatic amylase and maltase.

(d) In the Intestinal juice—Intestinal amylase, maltase, lactase, sucrase etc.

III. Mechanism of Digestion of Carbohydrate Food stuffs :

(A) Polysaccharide Splitting Enzymes :

(a) Action of Salivary amylase or Ptyalin : It is secreted from the parotid gland and acts on boiled starch in slightly acid or neutral or slightly alkaline medium with an optimum temperature about 45°C. The boiled starch (100%) after activation of ptyalin converts into maltose (80%) and the rest 20% converts into Isomaltose which resists for further action of ptyalin. The stages of breakdown of boiled starch by ptyalin is given below :


Boilled (Soluble) Starch (100%)
Salivary gland→Saliva→Ptyalin→
(Parotid)
←Slightly acidic or alkaline or neutral media
(Red colour with Iodine)...Erythro-dextrin
Maltose
(No Colour with Iodinel)...Achroo-dextrin
Maltose
Isomaltose (20%)
Maltose (80%)

(b) Action of Pancreatic amylase : It is liberated from the pancreatic gland and acts on both boiled and unbolied starch in alkaline medium with an opitimum temperature about 45°C. After the activation of pancreatic amylase, both boiled and unboiled starch convert into Isomaltose (20%) and maltose (80%). The stages of breakdown of boiled and unboiled starch by pancreatic amylase are as follows :

PANCREAS→Pancreatic amylase→Starch
in alkaline media (Both boiled and unboiled)
↓
Achroo-dextrin+Maltose←Erythrodextrin+Maltose
↓
Isomaltose+Maltose.

(c) Action of Intestinal amylase : It is secreted from the intestinal glands and acts on unboiled strach in alkaline media which converts into Isomaltose and maltose. The stages of breakdown of unboiled starch by intestinal amylase are as follows :

INTESTINE→Intestinal amylase→Unboiled Starch→Maltose + Erythrodextrin→Maltose+ Achroo-dextrin→Isomaltose+Maltose.

(B) **Disaccharide Splitting Enzymes :**

(a) **Action of Maltase** : It is liberated from the salivary glands, stomach, pancreas and intestine. It acts on maltose either in acid or neutral or alkaline media and converts into two molecules of glucose.

$$\underset{\text{(Maltose)}}{C_{12}H_{22}O_{11}} \xrightarrow[+H_2O]{\textit{Maltase}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(glucose)}}{C_6H_{12}O_6}$$

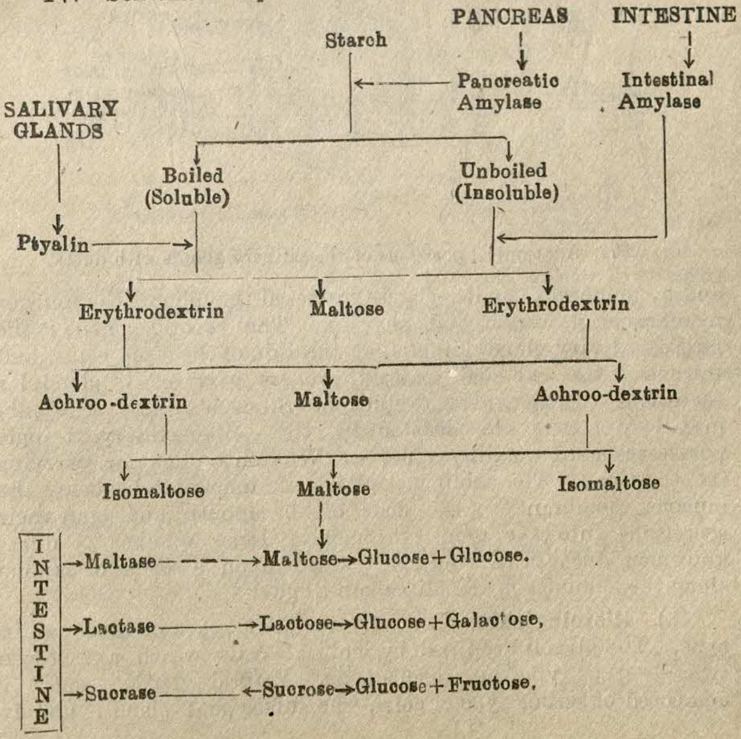
(b) **Action of Lactase** : It is liberated from the intestinal glands and acts on lactose in alkaline media and converts into one molecule of glucose and one molecule of galactose.

$$\underset{\text{(Lactose)}}{C_{12}H_{22}O_{11}} \xrightarrow[+H_2O]{\textit{Lactase}} \underset{\text{(Glucose)}}{C_6H_{12}O_6} + \underset{\text{(Galactose)}}{C_6H_{12}O_6}$$

(c) **Action of Sucrase or Invertase** : It is liberated from intestinal glands and acts on sucrase in alkaline media which converts into one molecule of glucose and one molecule of fructose.

$$\underset{\text{(Sucrose)}}{C_{12}H_{22}O_{11}} \xrightarrow[+H_2O]{\textit{Sucrase}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(glucose)}}{C_6H_{12}O_6}$$

IV. Schematic representation of Carbohydrate digestion :



Therefore, the end products of carbohydrate digestion are the glucose, galactose and fructose, etc. which have been formed by the activation of different types of carbohydrate splitting enzymes.

Q. 8. Describe the structure of the Salivary glands and discuss the composition and function of Saliva.

Salivary glands are of three pairs, situated within the different regions of the mouth cavity, secretes saliva which help in the process of carbohydrate digestion mainly.

Structure of Salivary glands :

(a) **Anatomical** : There are three pairs of salivary glands such as parotid, submaxillary and sub-lingual glands and by numerous smaller glands scattered thoughout the mucous membrane of mouth and pharynx. The parotid gland is the largest salivary gland, situated at the side of the face below and infront of the ear and mastoid process, carrying its glandular secretions through parotid duct or Stensen's duct. The sub-maxillary glands are situated in the sub-maxillary traingle possessess a sub-maxillary duct or Whaton's duct for carrying its secretions. The sublingual glands lie immediately below the mucous membrane of the floor of the mouth and pour their secretions into the mouth through a large number of ducts known as duct of Rivinus and open upon a series of papillæ along the summits of the plicae sub-lingualis.

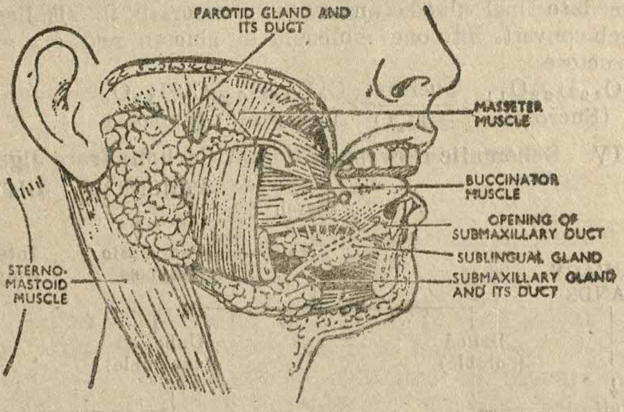

PAROTID GLAND AND ITS DUCT
MASSETER MUSCLE
BUCCINATOR MUSCLE
OPENING OF SUBMAXILLARY DUCT
SUBLINGUAL GLAND
SUBMAXILLARY GLAND AND ITS DUCT
STERNO-MASTOID MUSCLE

Fig. 17. Anatomical positions of the salivary glands with ducts.

(b) **Histological** : The salivary glands are of racemose in type. The alveoli are lined by cubical cells which are of two types—serous type and mucous type. Parotid gland is entirely composed of serous type of cells, the sub-lingual gland is mainly composed of mucous type of cells and the sub-maxillary gland is of mixed type. In serous cell, the cytoplasm is granular and the granules possess very fine zymogen granules. The nucleus is in the centre. In mucous cell, the granules are coarse and the nucleus is centric.

Physical Properties of Saliva :

(1) **Nature :** It is colourless, cloudy and slimy due to the presence of epithelial cells, lymphocytes and mucin.

(2) **Amount secreted per day :** It becomes 1200 ml. to 1500 ml.

(3) **Output of the resting gland :** It is only obout 0·35 ml per minute.

(4) **PH :** It was found to vary between 6·35 and 6·85.

(5) **Reaction :** It is neutral in reaction but according to Starr, it is a slightly acid in reaction.

(9) **Specific gravity :** Between 1002 and 1012.

(7) **Freezing point :** It becomes 0·07° to 0·34°C.

Chemical Composition of Saliva :

(A) **Water :** 99·5%

(B) **Gases :** Carbon dioxide, Oxygen and Nitrogen.

(C) **Total solids :** 0·5%

Organic Substances (0·3%)

Enzymatic

1. Ptyalin or Salivary amylase.
2. Maltase.
3. Lysozyme.
4. Kallikrein.
5. Carbonic anhydrase.
6. Phosphatase.

Non-enzymatic

1. Serum Albumin.
2. Serum Globulin.
3. Urea and Uric acid.
4. Creatine and Amino-acids
5. Mucin and Bacteria.

Inorganic Substances (0·2%)

1. Sodium and Potassium Chloride.
2. Sodium Bi-carbonate.
3. Acid and Alkaline Sodium phosphate.
4. Calcium Carbonate and Calcium phosphate,
5. Potassium Sulpho-cyanate.

Functions of Saliva :

The functions of saliva is broadly divided into digestive and non-digestive functions.

I. Digestive Functions :

(a) **Function of Ptyalin ;** It is liberated from the parotid gland and acts on boiled starch in neutral or slightly acid media and converts into Isomaltose (20%) and maltose (80%). The stages of breakdown is as follows :

Boiled Starch + Ptyalin → Maltose + Erythrodextrin → Maltose + Achroodextrin → Isomaltose + Maltose.

(b) **Function of Maltase :** Maltase acts on maltose in neutral or slightly acid media and converts into two molecules of glucose.

(c) **Function of Lysozyme :** It is a bacteriocidal enzyme, present also in the lacrymal secretion, has a destructive action upon staphylococci, streptococci, meningococci. It has a mucolytic action and has anti-bacterial activity to its ability to dissolve the polysaccharide in the capsule of the microorganisms.

(d) **Function of kallikrein :** It produces *kallidin* or *Bradykinin* after acting upon plasma protein. It produces vasodilatation of salivary gland during secretion and causes sudden fall and consequent rise of blood presure.

II. Non-digestive Functions :

(A) General Functions :

(a) **Swallowing mechanism :** Saliva helps in the process of swallowing of food stuffs after moistened with saliva, enabling it to be rolled into plastic mass and form bolous that enter into the oesophagus.

(b) **Solvent action :** Saliva acts as a solvent action possessing chemical sense in the tongue and stimulates taste buds by the food stuffs.

(c) **Cleansing action :** The constant flow of saliva keeps the mouth and teeth clean by inhibiting the bacterial growth.

(d) **Lubrication action :** Saliva serves the functions of lubrication of the soft parts of the mouth, pharynx and oesophagus.

(e) **Articulation of Speech :** By fascilitating movements of tongue and lips, it makes rapid articulation of speech possible.

(f) **Excretory function :** Saliva excretes urea, heavy metals such as mercury, lead, bismuth, arsenic etc. thiocyanates and certain drugs such as potassium iodide, lead etc. It also excretes certain virulent micro-organisms such as virus of hydrophobia, acute anterior poliomyelitis, mumps, etc.

(g) **Temperature regulation :** Saliva helps in the regulation of body temperature by its variable srcretions in different seasons.

(h) **Water balance :** Saliva regulates the water balance of the body. In dehydration, salivary secretion is greatly decreased but when the blood volume is increased, salivary secretion is also increased.

(i) **Blood reaction :** Saliva helps to maintain the reaction of blood in the body.

(B) **Specific Functions :**

(a) **Functions of Mucin :** (1) It is an amphoteric compound by which the pH of juice is maintained. (2) It helps to prepare the inner lining membrane of the buccal cavity. (3) It serves as a mobilization and lubricating action over different food stuffs. (4) It maintains hydrogen-ion-concentration of the juice.

(b) **Functions of Inorganic Salts :** (1) The phosphates and bicarbonates act as a buffer. (2) The chloride helps for the activation of salivary amylase over boiled starch. (3) The calcium salt is soluble in acid and insoluble in alkali media throughout when pH rises. (4) The carbonate and phosphate of calcium deposits upon tooth and form tartar and may produce salivary calculi. (5) The potassium sulphocyanate is an excretory product formed within the body from cyanogen (—CN) radicals and derived from protein metabolism. It is found in excess in amount in saliva of habitual smokers.

Q. 9. Describe the mechanism of secretion of Saliva.

Saliva is one of the digestive juice, secreted from the salivary glands. Its mechanism of secretion depends upon the method of collection, nerve supply and mechanism.

Method of Collection : The saliva is collected through the fistula in the parotid duct.

To collect pure saliva unmixed with food, a canula is inserted into the parotid duct and through this all the saliva secreted by the gland is collected outside. Saliva may also be collected from an opening in the duct which is transplanted upon the outer surface of the cheek.

Nerve Supply : The salivary glands are supplied both by sympathetic and parasympathetic fibres. The *sympathetic fibres* take origin from *1st* and *2nd* thoracic segments. The preganglionic fibres will relay in superior cervical ganglia from which post-ganglionic fibres will supply the parotid gland forming a plexus over the internal carotid artery and sub-mandibular and sub-lingual glands forming a plexus over the external carotid artery. The *parasympathetic fibres* supply in this way : The parotid gland is supplied by *9th* nerve through otic ganglion and sub-maxillary and sub-mandibular glands are supplied by facial nerve (*7th*) through sub-mandibular ganglia. The sympathetic stimulation will cause water content of the juice and parasympathetic stimulation will cause enzymatic secretion of the juice.

Mechanism of Secretion : Under ordinary conditions the secretion of saliva is absolutely a reflex process.

(*a*) **Conditioned reflex :** The stimulus which initiates the reflex is not applied to the nerves of mouth but is received by one or other organs for special sense e.g., sight, smell etc.

(*b*) **Unconditioned reflex :** The materials placed in the mouth cavity callforth after a short latent period, a secretion of saliva which varies in quality and quantity according with the physical and chemical substances are introduced. The sensory stimulus for this reflex may arise from various sources as follows :

(1) *Mouth-Salivary reflex* : The mouth is the chief place from which normal unconditioned stimulus for salivation occurs. The irritation is caused by the presence of food upon the mucous membrane of mouth and acts as the sensory stimulus which reflexly produces salivation.

(2) *Oesophago-Salivary reflex* : The sensory stimulus may rise from the oesophagus. When the food passes down the oesophagus, salivation is started. The ulcer, cancer or the presence of foreign body in the oesophagus may stimulate salivation.

(3) *Gastro-Salivary reflex* : The sensory stimulus may arise from the mucous membrane of the stomach. The gastritis, gastric cancer etc, may stimulate salivation.

(4) *From other Viscera* : The sensory stimulus for salivation may arise from other viscera. During pregnancy, increased salivation occurs from the sensory stimulus arising from the distended uterus.

Besides the nervous mechanism, there is possibility of a local hormonal mechanism by the liberation of *Bradykinins* which acting upon the blood vessels of the salivary glands produce vasodilatation and resulting increased secretion of salvia.

Q. 10. Describe the structure of Stomach and discuss the composition and functions of Gastric Juice.

Gastric juice is one of the digestive juice, secreted from the different types of gastric glands which helps in the process of digestion of different types of food stuffs.

Structure of the Stomach :

The stomach is a J-shaped structure possessing three parts—the fundus, the body and the pylorus. Histologically, stomach consists of four layers from outside inwards. These are outer

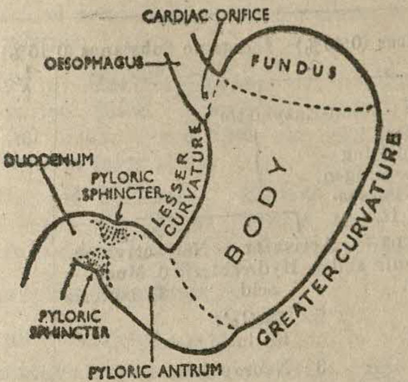


Fig. 18. Anatomical structure of the stomach showing its different parts.

serous coat, middle muscular coat comprising circular, longitudinal and oblique muscle fibers, the inner sub-mucous coat and the innermost mucous coat which contains three types of gastric glands. The gastric glandular cells are the chief cells or central cell or peptic cells, the parietal oxyntic cells and the mucous cells. The chief or peptic cells are short, columnar glandular cells which secretes an enzyme known as inactive pepsinogen. The parietal or oxyntic cells are large oval cells which secrete hydrochloric acid. The mucous cells are of isthmus cells and neck cells which secrete mucin.

Physical Properties of Gastric Juice :

(1) **Nature :** It is a colourless, cloudy and slimy fluid due to the presence of mucin.

(2) **Amount secreted per day :** It becomes 1500 ml. to 3000 ml.

(3) **PH :** It was found to be 0 9 to 1·5

(4) **Reaction :** It is strongly acidic in reaction.

(i) Free Hydrochloric acid : 0·4% to 0·5%

(ii) Total Acidity : 0·45 % to 0·6%.

(5) **Specific gravity :** Between 1006 to 1010.

(6) **Freezing point :** It becomes 0·59°C.

Chemical Composition of Gastric Juice :

(A) **Water :** 99·45%.

(B) **Gases :** Carbon dioxide, oxygen and nitrogen.

(C) **Total solids : 0·55%**

- Organic Substances (0·40%)
  - Enzymatic
    - 1. Proteolytic :
      - (i) Protein splitting— Inactive pepsingen. Gastricin, Parapepsin I and II.
      - (ii) Milk curding— Gastic rennin and Cathepsin.
    - 2. Lipolytic ; Gastric lipase,
    - 3. Amylolytic : Maltase—if present.
  - Non-Enzymatic
    - Activator
      - 1. Hydrochloric acid.
      - 2. Castle's intrinsic factor.
      - 3. Neuropoietic factor,
    - Non-activator
      - 0, Muc
      - 2. Bacteria.
- Inorganic Substances (0·15%)
  - Cations
    - 1. Sodium.
    - 2. Potassium.
    - 3. Calcium.
  - Anions
    - 1. Phosphate.
    - 2. Sulphate.
  - Extraneous Substances
    - 1. Ether and Sulphonamide.
    - 2. Drugs, Iodides and Bromides.
- Hormones
  - 1. Gastrin.
  - 2. Entero-gastrone.
  - 3. Urogastrone.

Functions of Gastric Juice :

The functions of gastric juice is broadly divided into digestive and non-digestive functions.

I. Digestive Functions :

(a) **Function of Inactive Pepsinogen :** It is liberated from the peptic cells of the stomach and converts into active pepsin with the help of hydrochloric acid. It acts upon acid metaprotein and converts upto peptone stage. The stages of digestion of acid metaprotein by active pepsin are Primary Proteoses→Secondary Proteoses→Peptone.

The active pepsin also acts upon nucleoprotein along with hydrochloric acid in acid media and breaks down into nuclein and one molecule of protein.

(b) **Function of Gastric Rennin or Rennet :** It is a milk curdling enzyme secreted from the stomach and acts upon caseinogen of milk, thereby converting it into proteose like substance such as "whey protein" and soluble casein. It will again combine with ionised calcium and form insoluble calcium caseinate that is "curd". The curd is the protein and it is acted by different types of protein splitting enzymes and forms amino-acids finally.

(c) **Function of Cathepain** : It is an accessory milk curdling enzyme that acts upon caseinogen of milk and converts into whey and curd or insoluble calcium caseinate after activation of ionised calcium.

(d) **Function of Gastric lipase** : It is a lipolytic enzyme present in the gastric juice. It acts on neutral fats in slightly acid medium and breaks down into one molecule of glycerol and three molecules of fatty acids.

(e) **Function of Maltase** : Maltase is generally absent in the gastric juice but if it is present, then it can act upon maltose and breaks down into two molecules of glucose.

II. Non-Digestive Functions :

(A) General functions :

(a) **Temperature regulation** : Gastric juice helps in the regulation of body temperature by its variable secretions in different seasons.

(b) **Water balance** : Gastric juice controls water balance of the body. In dehydration, gastric secretion is greatly decreased but when the blood volume is increased, gastric secretion is also increased.

(c) **Blood reaction** : Gastric juice helps to maintain the reaction of blood in the body.

(d) **Acid-base balance** : Gastric juice maintains the normal acid-base balance of the juice and the body fluids.

(e) **Excretory function** : Gastric juice excretes toxins, heavy metals such as mercury, lead, bismuth etc. and certain alkaloids.

(B) Specific functions :

(a) **Functions of Hydrochloric acid** : (i) It kills foreign bacteria. (ii) It converts protein into acid metaprotein. (iii) It helps in the conversion of inactive pepsinogen into active pepsin. (iv) It acts upon nucleo-protein along with active pepsin and breaks down into nuclein and one molecule of protein. (v) It acts upon caseinogen of milk along with Gastric Rennin and converts into whey protein and soluble casein. (vi) It regulates acid-base balance and blood reaction.

(b) **Function of Castle's Intrinsic factor** : It combines with Castle's extrinsic factor and forms Castle's haematinic principle. This principle helps in the development of erythrocytes by converting megaloblast into early erythroblast stage.

(c) **Function of Neuropoietic factor** : It helps and supplies the nutrition of the spinal cord.

(d) **Functions of Mucin :** (i) It is an amphoteric compound by which the pH of the juice is maintained. (ii) It helps to prepare the inner lining membrane of the stomach. (iii) It serves as a mobilisation and lubricating action over different food stuffs and thereby digested food stuffs can easily pass from one place to the other. (iv) It maintains hydrogen-ion-concentration of the juice.

Q. 11. Describe the mechanism of secretion of Gastric Juice.

The gastric juice is one of the digestive juice, secreted from the gastric glands. Its mechanism of secretion depends upon the method of collection, nerve supply and mechanism.

Methods of Collection : The method of collection of gastric juice is done by Sham feeding experiment and Pavlov's pouch.

(a) **Sham feeding Experiment :** The oesophagus of a dog is dissected out and divided into two halves into the neck. Both the cut ends are sutured in the skin of the neck. After swallowing of the food, it will come out through the upper cut end of the oesophagus and by introducing the Ryle's tube through the lower cut end, the gastric juice can be obtained.

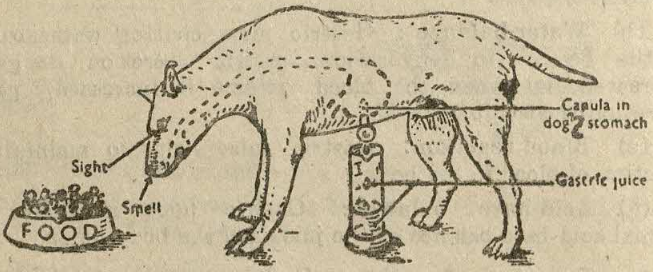


Fig. 19. Soam feeding Experiment shown in dog.

(b) **Pavlov's Pouch Experiment :** An incision is given through the greater curvature of the stomach to prepare the greater stomach. Both the stomachs are separated by suturing their walls and inner mucous membrane. The miniature stomach is then brought to the exterior through the skin wound and sutured with the skin wound, the blood supply and nerve supply are kept intact.

Nerve Supply : The stomach is supplied by sympathetic nerve which will take origin from 6th to 12th thoracic segments. The pre-ganglionic fibres will relay in coeliac ganglia from where the post-ganglionic fibres will supply the gastric glands. The stimulation of sympathetic nerve will inhibit the gastric secretion and the watery content of the juice is increased.

The stomach is also supplied by parasymapathetic nerve i.e., vagus which will arise from the 10th cranial nerve nuclei of the medulla oblongata. The stimulation of vagus will cause profuse sscretion of gastric juice and the enzymatic portion of the gastric juice is increased.

Mechanism of Secretion : The mechanism of secretion of gastric juice is done by nerves and chemical agents.

(a) **Nervous Mechanism** : It is done by conditioned and unconditioned reflexes. (1) *Conditioned reflex :* The smell, sight, learning will cause reflex secretion of gastric juice. The afferent fibres are olfactory, optic, auditory which will carry the impulses to the cerebral cortex which then stimulates the gastric centre and the efferent vagus from the dorsal nucleus will cause the impulses and will stimulate the gastric gland to secrete gastric juice. (2) *Unconditioned reflex* : When the food enters the stomach, gastric secretions start. The impulses from the stomach will pass through afferent fibres which will relay in the dorsal nucleus of vagus and the efferent fibres of vagus will stimulate the gastric gland to secrete gastric juice.

(b) **Chemical Mechanism** : The chemical mechanism is served by gastric and intestinal phase. (1) **Gastric Phase** : All the nerves supplying the stomach are cut, yet after the introduction of food into the stomach there will be secretion of gastric juice. This is due to the liberation of a hormone known as *gastrin* from the pyloric mucous membrane. It is a polypeptide and its chemical nature is like Histamine. The injection of extracts of pyloric mucous membrane will cause secretion of gastric juice. (2) **Intestinal Phase** : When acid chyme enters the duodenum, there will be liberation of another hormone from the wall of the upper part of the small intestine known as *Intestinal gastrin*, which will also stimulate gastric gland to secrete gastric juice. When fat or fatty milk enters the duodenum, there will be liberation of another hormone, called *Enterogastrone* which will inhibit the gastric secretion and movement of the stomach. The injection of *urogastrone* found in the urine, will also inhibit the secretion of gastric juice and movement of the stomach.

Q. 12. Describe the origin and formation of Hydrochloric acid.

The parietal cells of the fundic glands are responsible for the production of the acid and water of the gastric juice. The gastric glands secreted some unknown products which upon reacting the surface of the gastric mucosa give rise to the formation of hydrochloric acid.

Theories concerned in HCL Formation: There are a number of theories put forward for establishing the secretion of HCL, which are discussed below ;

I. **Zonal Equilibrium Theory** : The mechanism of secretion of HCL is done by the equilibrium of chloride, phosphate and bicarbonate. The parietal cells secrete a neutral protein chloride which becomes acid only upon reacting the surface of the gastric mucosa. The cells secrete a dilute acid and stronger and a stronger acid is formed by reabsorption of water in the tubules until gastric juice becomes isotonic with blood.

II. **Modern Theory** : The H^+ ions derived from water or from hydrogen which is removed during dehydrogenase activity. The removal of H^+ ions result in the formation of excess OH^- ions. The resulting alkalinity tends to destroy the secretory cells, hence CO_2 is required to neutralise this. The high concentration of carbonic anhydrase in the parietal cells helps in the hydration of CO_2 to produce carbonic acid, which is utilised for the neutralisation of OH^- ions produced during secretion. $CO_2 + H_2O + NaCl \rightleftarrows NaHCO_3 + HCL$.

III. **Maly's Theory** : The oxyntic cell are rich in Sodium chloride and Phosphates. *Maly* believed that vital reactions represented by the following equations were responsible for the formation of hydrochloric acid.

$$Na_2HPO_4 + H_2CO_3 \rightarrow NaH_2PO_4 + NaHCO_3$$

$$NaH_2PO_4 + NaCl \rightarrow Na_2HPO_4 + HCL.$$

These reactions take place in the cellular layer of oxyntic cells.

IV. **Theory of Davenport** : According to *Davenport* in 1959, the secretion of HCL is a cyclic process of oxidation and reduction. He summed up his views as follows : The secretory mechanism consists of atleast four parts : (1) Aerobic and anaerobic reaction in the parietal cells produce high energy phosphate bonds. These provide energy to drive the secretory reactions. (2) The secretory reactions may be indicated in three steps : (i) One high energy phosphate bond combines with a reduced low-energy precursor to form a reduced high-energy precursor. (ii) The high-energy compound is oxidised yieldng a H^+, a low-energy precursor and an electron. (iii) The oxidised low energy precursor becemes reduced by substrate electrons and is available to undergo reaction. (3) The electron liberated is finally accepted by oxygen. One O_2 molecule is reduced for each four H^+ secreted producing four hydroxyl ions. Four electrons are required to produce $2\,OH^-$ from O_2. (4) The OH^- produced are neutralised by various buffers, including the system, $CO_2+H_2O \rightarrow H_2CO_3$ and $H_2CO_3 \rightarrow H^+ + HCO_3^-$ in which case the H^+ reacts with the OH^- to form water.

V. **Electrophysiologic Theory of Rehm and Dannis :** The electrophysiologic theory of gastric HCL production is reviewed by *Rehm* and *Dannis* in 1950. *James* reviewed the entire field of hydrochloric acid formation.

Rehm and his co-workers have shown that there is a natural, maintained potential difference across the gastric mucosa, the secretory surface being negative in an external circuit to the nutrient surface. When the two sides of the mucosa are connected electrically a continuous current can be maintained and the natural potential decreases with the onset of acid secretion.

VI. **Theory of Davies and Ogston :** Hydrogen ions, formed by ionization from water, are concentrated in an electron cycle mechanism involving this cytochrome system, which transport them into the canaliculus of the gastric glands. The energy required for this transport is derived from energy-rich compounds such as creatine phosphate. Simultaneously, a chloride ion passes from the oxyntic cells into the canaliculus to preserve electrical neutrality. The hydroxyl ion of water ionised reacts with CO_2 to form bicarbonate under the influence of enzymic carbonatic anhydrase which is abundant in the gastric mucosa. The bicarbonate ions pass into the blood stream while chloride ions pass into the canaliculus. For the secretion of each hydrogen ion into the canaliculus one bicarbonate ion is secreted in the opposite direction into the blood and causes "alkaline tide" of urine. The overall reaction may be represented by the equation :

$$2H_2O + 2Cl^- + 2CO_2 + \text{Creatine Phosphate} \rightarrow$$
$$2H^+ + 2Cl^- + 2HCO_3^- + \text{Creatine} + \text{Phosphate}$$

Q. 13 Describe the structure of the Pancreas and discuss the composition and functions of Pancreatic Juice.

Pancreatic juice is one of the digestive juice secreted from the pancreatic cells which serves the function of digestion of different food stuffs.

Structure of the Pancreas : Pancreas is tubulo-racemose gland, situated within the second part of the duodenum and lies across the vertebral column with a duct to carry external secretion, rich in enzyme, delt with in connection with the digestive system. The central part of the pancreas formed by islets cells of Langerhans, responsible for the internal secretion such as insulin which acts as an anti-diabetogenic factor.

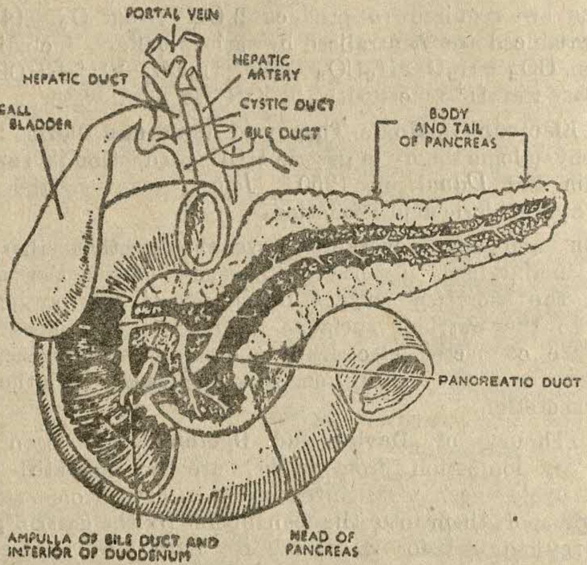


Fig. 20. Anatomical position of Pancreas showing its relations.

The outer or exocrine part of the pancreatic gland contains numerous alveoli with elongated tubule, lined by columns of

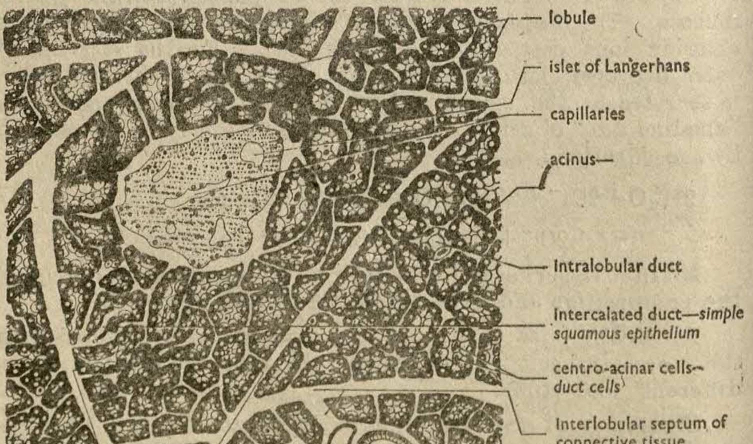

lobule
islet of Langerhans
capillaries
acinus—
intralobular duct
intercalated duct—*simple squamous epithelium*
centro-acinar cells—*duct cells*
interlobular septum of connective tissue
interlobular duct—*simple columnar epithelium*
lobule
blood vessel

Fig. 21. Structure of Pancreas showing its different microscopic elements.

polyhedral cells. The inner two-thirds of which are full of granules, the precursors or the zymogen granules by means of which normal pancreatic juice are secreted.

The central or endocrine part possesses groups of cells, with no ducts, but with a close network of capillaries, known as Islets of Langerhans, situated scatteredly in between the alveoli. There are four types of Islet cells such as ∝, β, γ and δ cells. The ∝-cells produce lipocaic and glucagon, β-cells produce insulin but γ-and δ-cells serve as a mother cell

Physical properties of Pancreatic Juice.

(1) **Nature :** It is a colourless, odourless, alkaline fluid of low viscosity and testing strongly of sodium bicarbonate.

(2) **Amount secreted per day :** It becomes 1000 to 1500 ml.

(3) **PH :** Between 8·0 and 8·3.

(4) **Reaction :** It is alkaline in reaction.

(5) **Specific gravity :** Between 1010 and 1028.

Chemical Composition of Pancreatic juice,

(A) **Water :**99·4%.

(B) **Gases :** Carbon dioxide, Oxygen and Nitrogen.

(C) **Total Solids :** 0·6%

- Organic Substances
  - Enzymatic
    - 1. Proteolytic
      - (i) Protein splitting— Inactive trypsinogen, Procarboxypeptidase, Nucleotidases, Collagenase.
      - (ii) Milk Cudling— Chymotryrpsin.
    - 2. Lipolytic Pancreactic Lipase, Lecithinase, Cholesterolesterase.
    - 3. Amylolytic
      - (i) Pancreatic amylase.
      - (ii) Maltase.
  - Non-Enzymatic
    - 1. Mucin.
    - 2. Bacteria.
- Inorganic Substances
  - Cations
    - 1. Sodium
    - 2. Potassium.
    - 3. Calcium.
    - 4. Magnesium.
  - Anions
    - 1. Phosphate
    - 2. Sulphate.
    - 3. Carbonate.
    - 4. Chloride.
- Hormones
  - 1. Secretin.
  - 2. Pancreozymin.

Functions of Pancreatic Juice : The functions of pancreatic juice is broadly divided into digestive and non-digestive functions.

I. Digestive Functions :

(a) **Functions of Inactive Trypsinogen** : It becomes active by the action of enterokinase which is present in the intestinal juice. The active trypsin thus formed act upon alkali metaprotein and converts into polypeptide stage. The stages of breakdown are Primary proteoses→Secondary proteoses →Peptones→Polypeptides.

The active trypsin also acts upon nuclein of nucleoprotein in alkali media breaks down into nucleic acid and one molecule of protein.

(b) **Funciton of Chymotrypsin :** It is an accessory milk curdling enzyme, acts upon caseinogen of milk and converts it into whey protein and soluble casein.

(c) **Function of Pancreatic Lipase** : It is a lipolytic enzyme present in the pancretic juice. It acts on neutral fats in alkaline media and breaks down into one molecule of glycerol and three molecules of fatty acids.

(d) **Function of Pancreatic Amylase** : It acts both on boiled and unboiled starch in alkaline medium with an optimum temperature about 45°C. After activation of pancreatic amylase, both boiled and unboiled starch convert into Isomaltose (20%) and maltose (80%). The stages of breakdown of both boiled and unboiled starch by pancreatic amylase are as follows :

Pancreatic amylase→Boiled and Unboiled Starch.
↓
Achroo-dextrin+Maltose←Erythrodextrin+Maltose
↓
Isomaltose+Maltose.

(f) **Function of Maltase** : Maltase acts upon maltose in alkaline media and breaks down into two molecules of glucose.

II. Non-digestive functions :

(A) **General functions** :

(a) **Temperature regulation** : Pancreatic juice helps in the regulation of body temperature by its variable secretions.

(b) **Water balance** : Pancreatic juice maintains water balance of the body. In dehydration, pancretic secretion is greatly decreased but when the blood volume is increased, pancrertic secretion is also increased.

(c) **Blood reaction** : Pancreatic juice helps to maintain the reaction of blood in the body.

(d) **Acid-base balance** : Pancreatic juice maintains the normal acid-base balance of the juice and the body fluids.

(e) **Excretory functions** : Pancreatic juice excretes toxins and heavy metals such as mercury, lead, bismuth, arsenic etc.

(B) **Specific functions** :

Functions of ucin : (1) It is an amphoteric compound by which the pH of the juice is maintained. (2) It helps to prepare the inner lining membrane of the pancreatic duct and the small intestine. (3) It serves as a mobilisation and lubricating action over different food stuffs and thereby digested food stuffs can easily pass from one place to the other (4) It maintains acid-base balance of the juice.

Q. 14. Describe the mechanism of secretion of Pancreatic Juice.

The pancreatic juice is one of the digestive juice, secreted from the pancreatic glands. Its mechanism of secretion depends upon the method of collection, nerve supply and mechanism.

Method of Collection : The second part of the duodenum with the pancreatic duct is brought through the abdominal wound and sutured with the abdominal skin.

Nerve Supply : The pancreas is supplied by sympathetic nerve which will take origin from 6th to 12th thoracic segments. The pre-ganglionic fibres will supply the pancreatic glands. The stimulation of sympathetic nerve will inhibit the gastric secretion and the watery content of the juice is increased.

The pancreas is also supplied by parasympathetic nerve i.e., vagus which will arise from the medulla oblongata. The stimulation of parasympathetic nerve will cause profuse secretion of pancreatic juice and the enzymatic portion of the pancreatic juice is increased.

Mechanism of Secretion : The mechanism of secretion of pancreatic juice is done by nerves and chemical agents.

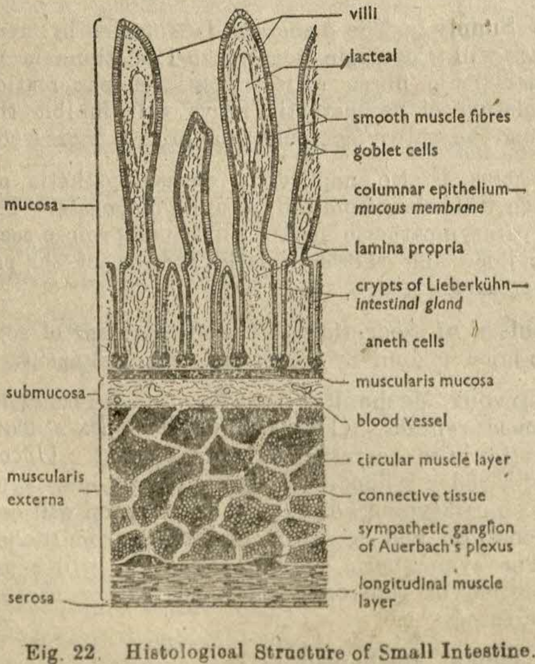
(a) **Nervous Mechanism** : It is done by conditioned and unconditioned reflexes. (1) *Conditioned reflex* : This reflex in pancreatic juice secretion is absent. (2) *Unconditioned reflex* : This reflex is done by parasympathetic and sympathetic nerves. The parasympathetic nerve stimulation will cause more enzyme secretion and less salt formation from the pancreatic glands The sympathetic nerve stimulation will cause inhibition of secretion of pancreatic juice and watery content of the juice is increased.

(b) **Chemical Mechanism** : The chemical mechanism is done by Secretin and Pancreozymin. (1) *Secretin* : It is a polypeptide hormone of low molecular weight. It can be extracted from the mucosa of the duodenum and to a less extent of the upper small intestine. It produces a flow of watery, highly alkaline juice and almost devoid of enzymes. (2) *Pancreozymin* : It is resposible for secretion which is moderate in volume, poor in alkali and rich in enzyme. It appears to have similar chemical and physical properties as secretin. The pancreozymin and the vagal mechanism will increase its enzyme content.

Q. 15. Describe the structure of the Small Intestine and discuss the composition and function of Intestinal Juice.

Intestinal juice or succus entericus is one of the digestive juice, secreted from the intestinal glands and serves the function of digestion of different food stuffs.

Structure of the Small Intestine : The small intestine having roughly 25 feet in length, has got three parts—Duodenum, Jejunum and Ileum. Histologically, small intestine consists of four layers from outside inwards. These are outer serous coat middle muscular coat comprising outer circular and inner longitudinal, inner sub-mucous coat possessing Brunner's gland and the innermost mucous coat which contain villi and crypts to Lieberkuhn. The villi is the duplication and reduplication



Eig. 22. Histological Structure of Small Intestine.

of intestinal mucous folds lined by columnar epithelial cells containing central lacteal channels, blood capillaries, lymphatics and nerve plexuses. The crypts of Liberkuhn are the simple tubular glands which contain three types of cells known as coloumnar goblet and flask-shaped cells. These cells are responsible for the secretion of succus entericus.

Physical Properties of Intestinal juice.

(1) **Nature :** It is a thin, colourless or slightly straw-coloured fluid somewhat opalescent and coniaining flocks of mucous.

(2) **Amount secreted per day :** It becomes 1500 ml. to 2000 ml.

(3) **PH :** It was found to be 7·2 to 8·6.

(4) **Reaction :** It is faintly acidic to faintly alkaline in reaction.

(5) **Specific gravity ;** Between 1008 to 1012.

Chemical Composition of Intestinal juice.

(A) **Water :** 98·5%

(B) **Gases :** Carbon dioxide, Oxygen and Nitrogen.

(C) **Total Solids :** 1·5%

- Organic Subatances
  - Enzymatic
    - (a) Proteolytic
      - 1. Protein Splitting – Active Erepsin.
      - 2. Nucleoprotein Splitting – Nuclease, Nucleotidase, Nucleosidase.
      - 3. Arginase.
    - (b) Lipolytic – Intestinal Lipase.
    - (c) Carbohydrate Splitting –
      - 1. Polysaccharidases – Intestinal amylase.
      - 2. Disaccharidases –
        - (i) Maltase
        - (ii) Lactase
        - (iii) Sucrase.
        - (iv) Isomaltase.
  - Non-Enzymatic
    - Activator
      - 1. Entero-peptidase.
    - Non-activator
      - 1. Mucin.
      - 2. Bacteria
- Inorganic Substance
  - Cations
    - 1. Sodium.
    - 2 Potassium.
    - 3. Calcium.
    - 4. Magnesim.
  - Anions
    - 1. Phosphate.
    - 2. Sulphate.
    - 3. Carbonate.
    - 4. Chloride.
- Hormones
  - 1. Duocrinin.
  - 2. Vilikrinin.
  - 3 Enterocrinin.

Functions of Intestinal juice : The functions of intestinal juice is broadly grouped into two divisions such as digestive and non-digestive functions.

I. Digestive Functions :

(a) **Function of Active Erepsin :** It is a proteolytic enzyme, acts upon alkali metaprotein in alkaline media and breaks down into amino-acids stage. The stages of breakdown of alkali metaprotein by active erepsin is as follows : Alkali Metaprotein→Primary Proteoses→SecondaryProteoses→Peptone →Polypeptides→Amino-acids.

(b) **Function of Nuclease :** It is present in the succus entericus, acts upon nucleic acid in alkaline media and breaks down into four mononucleotides.

(c) **Function of Mononucleosidase :** It is found in the intestinal juice, acts upon mononucleosides in alkaline media and breaks down into nucleosides and phosphoric acid.

(d) **Function of Nucleosidase :** It is present in the intestinal juice acts upon nucleosides in alkaline media and breaks down into pentose carbohydrate and nitrogenous bases like purine base comprising thymine and cytosin.

(e) **Function of Arginase :** It is present in the succus entericus and acts on arginine producing urea and ornithine.

(f) **Function of Intestinal Lipase :** It is a lipolytic enzyme present in the intestinal juice and acts on fats in alkaline media which converts into fatty acids and glycerol.

(g) **Function of Intestinal Amylase :** It is secreted from the intestinal gland and acts on unboiled starch (insoluble starch) in alkaline media which converts into stable dextrin and maltose. The stages of breakdown of unboiled starch by intestinal amylase are as follows :

Unboiled Starch+Intestinal amylase+Alkali→Maltose+Erythrodextrin→Maltose+Achroodextrin→Isomaltose and Maltose.

(h) **Function of Maltase :** It is liberated from the glands of the intestine and acts on lactose in alkaline media which converts into two molecules of glucose.

(i) **Function of Lactase :** It is liberated from the intestinal glands and acts on lactose in alkaline media which converts into one molecule of glucose and one molecule of galactose

(j) **Function of Sucrase :** It is a disaccharide splitting enzyme secreted from the intestinal glands and acts on sucrose in alkaline media.which converts into one molecule of glucose and one molecule of fructose.

II. Non-digestive Functions :

(A) General functions :

(a) **Temperature regulation :** Intestinal juice helps in the regulation of body temperature by its variable secretions.

(b) **Water balance :** Intestinal juice maintains water balance of the body.

(c) **Blood reaction :** Intestinal juice helps to maintain the reaction of blood in the body.

(d) **Acid-base balance :** Succus entericus regulates the nomal acid-base balance of the juice and the fluids.

(e) **Excretory function** : The intestinal juice excretes toxins and heavy metals such as Mercury, Lead, Bismuth, Arsenic etc.

(B) **Specific functions :**

(a) **Function of Enteropeptidase ;** It is present in the intestinal juice and acts on inactive trypsinogen in alkaline media which converts into active trypsin that serves as a proteolytic enzyme.

(b) **Function of Mucin :** (i) It is an amphotoric compound by which the pH of the juice is maintained. (ii) It helps to prepare the inner lining membrane of the small intestine. (iii) It serves as a mobilization and lubricating action over different food stuffs by which they can easily pass from one place to the other. (iv) It maintains acid-base balance of the juice.

(c) **Function of Bacteria :** The bacteria of large intestine helps in the formation of Vitamin K or Coagulating factor which prevents further oozing of blood during accidental injury.

Q. 16. Describe the mechanism of secretion of Intestinal Juice.

The intestinal juice or succus entericus is one of the digestive juice, secreted from the intestinal glands. Its mechanism of secretion depends upon the method of collection, nerve supply and mechanism.

Method of Collection : The method of collection of intestinal juice is done by the following methods :

(a) **Thiry's method :** A small part of the intestine is cut from main intestine. One end is stitched and another end is sutured with the abdominal skin.

(b) **Vellous method :** A small part of the intestine is cut, both the cut ends are open and are sutured with the abdominal wound, blood vessels and nerve fibres are kept intact.

Nerve Supply : The intestine is supplied by sympathetic nerves which originate from 6th to 12th thoracic segments. The stimulation of sympathetic nerve will inhibit the secretion of intestinal juice. The intestine is also supplied by parasympathetic nerves or vagus and the stimulation of which will cause profuse secretion of succus entericus.

Mechanism of secretion : The mechanism of secretion of intestinal juice is done by nervous phase and chemical phase.

(*a*) **Nervous Phase** : It is done by conditioned and unconditioned reflex. (1) *Conditioned reflex* : Smell, sight, hearing etc. will cause reflex secretion of succus entericus. (2) *Unconditioned reflex* : When food enters into the intestine, there will be stimulation of local nerve plexus known as Meissner's plexus. The efferent vagus will stimulate the Crypts of Leiberkhun of succus entericus.

(*b*) **Chemical Phase** : It is done by secretin and enterocrinine. (1) *Secretin* : After section of the nerve fibres supplying the intestine if food is introduced into the intestine, secretin will occur due to liberation of a hormore from the wall of the upper part of intestine known as secretin. It is a polypeptide and it is secreted when acid chyme enters the duodenum. (2) *Enterocrinine* : There will be secretion of another hormone from the wall of the upper part of the small intestine known as enterocrinine which will also cause secretion of succus entericus.

Q. 17. Describe the Structure and Functions of Liver.

Liver, the largest gland of the body, situated in the upper and the right part of the abdominal cavity, composed of right lobe, left lobe, quadrate and caudate lobes, performs metabolism of proteins, fats and carbohydrates and secretes bile which helps in the absorption of fat.

Anatomical Structure : The liver, the largest gland in the body, is situated in the upper and the right parts of the

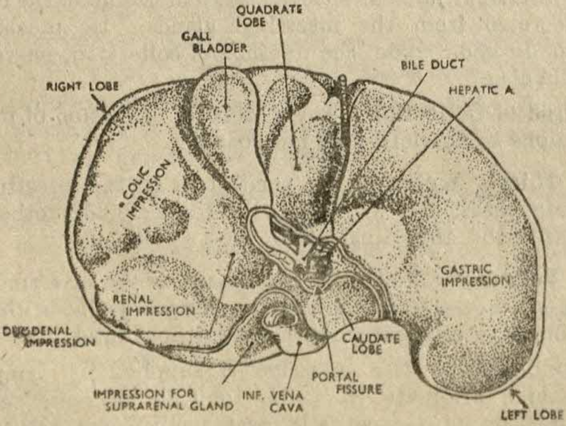


Fig. 23. Posterior surface of the Liver showing its different lobes and structures.

abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium and not uncommonly extending into the left hypochondrium as far as mammary line. In the male, it weighs from 1·4 to 1·6 kilogram, in the female, from 1·2 to 1·4 kilogram. The liver is divided into a large right and a much smaller left lobe. The portion of the right lobe joins with the left lobe on the interior and the posterior surfaces is further sub-divided into two smaller lobes known as quadrate and caudate lobes. At the inferior surface of the liver there is a deep transverse fissure known as porta hepatis through the excretory ducts of the liver leave and the hepatic arteries enter into the substance of liver. All the structures of the porta hepatis are surrounded by a fibro-fatty tissue called hepato-biliary or Glisson's capsule.

Histological Structure : Liver is almost a solid organ composed of several lobes. Each lobe is made up of numerous lobules. Each lobule consists of a mass of cells arranged in columns which radiates from a central vein like the spokes of a wheel. A row of polyhedral cells divide the liver lobule into a number of even compartments which are known as sinusoid and bile canaliculi that are arranged alternately. In between the two lobules there is a space occupied by portal canals which is internally lined by a loose connective tissue sheaths.

Functions of Liver : Liver is a chemical laboratory of the human being where all shorts of metabolism, blood formation, vitamin synthesis, heat regulation and many other performances are generally done in all the times. The major functions done by the liver are discussed below :

I. Functions concerning formed elements of blood :

(a) **Formation of Erythrocyte :** From mid-foetal life to late foetal stage, the liver is one of the main site of red cell formation.

(b) **Destruction of Erythrocyte :** Liver is a place where red blood cells are destroyed forming bilirubin and beliverdin which are excreted along with stool and urine.

(c) **Store house of Blood :** Spleen, is the store house of blood and during emergency, blood can come out into the circulation of liver by the constriction of the splenic vessels.

(d) **In connection with Blood Coagulation :** Liver manufactures prothrombin and fibrinogen that help in the process of coagulation.

(e) **Manufacture of Plasma protein :** Plasma protein is manufactured in the liver. *Whipple* by his classical experiments on dogs has shown that plasma proteins are formed from amino-acids derived from food.

(f) **Development of Erythrocyte** : Liver stores iron and Castle's haematinic factor and thus helps in the formation of red cells and haemoglobin.

II. **Functions concerning manufacture of Bile** : Bile is manufactured by the polygonal cells and the stellate cells of kupffer of the liver and thereby helps in the absorption of fat mainly.

III. Functions concerning General Metabolism.

(a) **In Carbohydrate Metabolism** : (1) In liver, the non-glucose monosaccharides are converted into glucose and then glycogen by the process of neoglucogenesis. (2) Lactic acid, pyruvic acid and glycerol are converted into glucose and then glycogen in the liver. (3) Glucose is converted into glycogen by the process of glycogenesis and it is stored in the liver. When blood sugar level is going low, mobilization of glycogen occurs and glycogen is converted into glucose by the process of glycogenolysis and it enters into the blood for maintaining normal blood sugar level. (4) Liver takes a very important role for the regulation of normal blood sugar level by the process of glycogenesis and glycogenolysis. (5) Liver is the seat of neoglucogenesis where the current glycogen is formed from the non-carbohydrates such as proteins and fats.

(b) **In Fat Metabolism** : (1) Liver is one of the store house of fat. (2) Desaturation ot fatty acids take place in the liver by the removal of the hydrogen ions and entrance of amino-group forming a peptide linkage. The products of desaturated fatty acids are stored in the liver for further oxidation. (3) The desaturation of fatty acid help in the synthesis of phospholipide which served in oxidation and transporation of fat. (4) Liver helps in the synthesis of fats from carbohydrates.and proteins. (5) The non-specific food fat may be converted into specific human fat in the liver. (6) Liver is perhaps the only site where ketone bodies are normally formed. The concentration of ketones is higher in the hepatic vein than in portal vein.

(c) **In Protein Metabolism** : (1) It is the seat of specific dynamic action of protein. (2) Liver is the chief place where de-amination occurs with the help of an enzyme deaminase. In this process, the amino radical is taken away from the amino-acids. (3) The metabolic end products of protein are the urea and uric acid which are fomed in the liver, (4) The synthesis of some amino-acids takes place in the liver.

(d) **In Nucleo-protein Metabolism** : The formation of uric acid takes place in the liver. The purine bases like adenine and guanine are absorbed from the succus entericus and through the portal circulation it will go to the liver. In the liver, adenine is converted into hypoxanthine by adinase. Hypoxanthine is then converted into xanthine by hypoxanthine oxidase. Xanthine is finally converted into uric acid by xanthine oxidase. Guanine is converted into xanthine which is converted into uric acid by xanthine oxidase. In some dogs, uric acid is converted into allantoin by uricase.

(e) **In Sterol Metabolism** : Certain of the steroid hormones particularly oestrogens are broken down into the liver.

IV. **Functions with relation of Vitamins** : (1) Liver can manufacture Vitamin A from carotenes specially from β carotene. (2) It manufactures prothrombin with the help of Vitamin K. (3) Liver stores Vitamin A and D. Vitamin A is stored in the human liver about 95% but the liver of the polar bear stores enermous amount of Vitamin A. (iv) Vitamin D is stored in the liver of such animal that does not possess any lungs. In the human liver, Vitamin. D cannot be stored but it is stored in the fish liver.

V. **Functions concerning Excretion** : (1) Certain heavy metals such as mercury, lead, bismuth, arsenic etc are temporarily fixed by the polyhedral cells of the liver and then excreted in the bile. (2) Various toxins, bacteria and drugs are excreted through bile from the liver. (3) Cholesterol and bile pigments such as bilirubin and biliverdin, are excreted from the liver through bile.

VI. **Functions concerning Protection** : (1) The harmful elements such as Indican, Hippuric acid, Benzoic acid, Glycuronic acid are conjugated with other elements forming a synthetic compound known as protective synthesis. The benzoic acid and glycine form hippuric acid and certain drugs combine with glycuronic acid are excreted from the liver through bile. (2) There are certain drugs such as strychnine, nicotine etc. are destroyed in the liver. (3) The reticulo-endothelial cells are phagocytic in nature and they can engulf the foreign particles and bacteria. (4) The reticulo-endothelial cells of the liver form antibodies which are concerned in function of protection of the body. (5) Liver protects the body by fixation and excretion. Liver cells help to fix.

VII. **Functions concerning Heat Regulation** : Due to various chemical reactions produced by the different metabolic processes of various food stuffs, liver produces large amount of heat and plays an important role in heat regulation.

Q. 18. Describe the structure of liver lobule and discuss the-composition, function and circulation of Bile.

Bile is a thick oily highly complex fluid secretes from the liver cells and stores in the gall bladder which serves the function of fat absorption, temperature regulation, water balance and absorption of fat soluble vitamins etc.

Structure of Liver lobule : Liver is the largest gland of the body, composed of several lobes. Each lobe is made up of a number of lobules. Each lobule possesses interlobular and intralobular structures.

(a) **Inter-lobular Structures** : These possess structures that are present in between the two lobules. The portal canal consists of following structures : (1) A branch of portal vein. (2) A branch of hepatic artery. (3) A tributary of hepatic duct. (4) Lymph vessels. (5) Sympathetic plexus.

(b) **Intra-lobular Structures** : These include structure that are present within a single liver lobule. The different structures of a liver lobule are polyhedral liver cells, sinusoids, kuffer's cell, central vein, bile canaliculi and ductules.

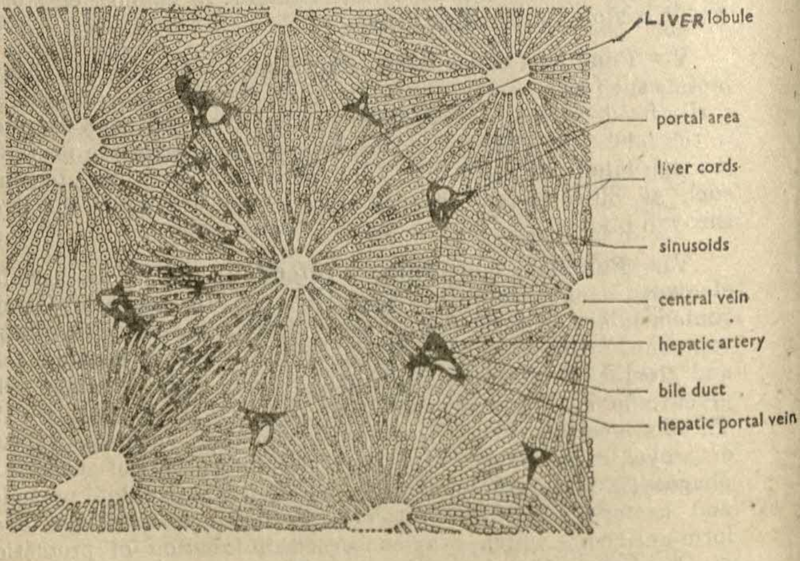


Fig. 24. Section of the liver lobule showing its inter – and intralobular structures.

Physical Properties of Bile :

(1) **Nature** : Bile is a thick oily highly complex fluid falls into the lumen of the intestine.

(2) **Colour** : Its colour is yellow in carnivora i.e. flesh eating animals ; green in herbivora i e , plant eating animals ; but in omnivora i.e , in man, its colour is yellowish green.

(3) **Odour** : Bile is fishy in odour.

(4) **Taste** : Bile is bitter in taste.

(5) **Amount secreted per meal** : (i) Total quantity : 500 to 1000 ml. (ii) Average weight of bile : 43 to 73 kgms.

(6) **pH orHydrogen-ion-Concentration** : (i) Human gall bladder bile : Neutral or slightly alkaline. (ii) Liver bile : Alkaline and pH between 8'0 and 8'6. (iii) Bile of dog or cat : Definitely acidic and pH between 5'0 and 6'0.

(7) **Specific Gravity** : (i) Liver bile : It becomes 1010 to 1012. (ii) Gall bladder bile : It becomes 1026 to 1030.

Chemical Composition of Bile :

(A) **Water** : 89%

(B) **Gases** : Carbon dioxide, Oxygen and Nitrogen.

(C) **Total Solids** : 11%

- Organic Subatances
  - Bile Salts
    1. Sodium taurocholate.
    2. Sodium glycocholate.
  - Bile Pigments
    1. Bilirubin.
    2. Billverdin.
  - Other organic Substances.
    1. Fatty acids.
    2. Cholesterol or Cholesterin.
    3. Lecithin and Fat.
    4. Traces of urea.
    5. Mucilaginous nucleo-albumin.
    6. Mucin.
    7. Bacteria.
- Inorganic Substances
  - Cations
    1. Sodium.
    2. Potassium.
    3. Calcium.
    4. Magnesium.
  - Anions
    1. Phosphate
    2. Sulphate.
    3. Carbonate.
    4. Chloride
- Hormones
  1. Bile.
  2. Cholecystokinin.

Functions of Bile : The functions of bile is broadly divided into general and specific functions.

I. **General functions of Bile** :

(a) **Temperature regulation** : Bile maintains in the regulation of body temperature.

(b) **Water balance :** Bile maintains normal water balance of the body.

(c) **Blood reaction :** Bile helps to maintain the normal reaction of blood in the body.

(d) **Acid-base balance :** Bile regulates the normal acid-base balance of the duodenal contents and thus helps the action of all enzymes. Bile is an important source of alkali for neutralising the hydrochloric acid after entering into the intestine.

(e) **Excretory function :** Bile excretes toxins, bacteria and heavy metals such as mercury, lead, bismuth, arsenic etc.

II. Specific functions :

(a) **Functions of Bile Pigments :** (i) The bile pigments helps in the formation of hæm which is mixed up with the globin part and ultimately forms fresh hæmoglobin. (ii) A part of the bile pigments is excreted along with stool as stercobilin while the remaining part is excreted out by the kidneys as urinary pigments known as urobilin uroerythrine and urochrome. (iii) The bile pigments fascilitate the absorption of iron and other substances which are necessary for the synthesis of hæmoglobin.

(b) Functions of Bile Salts :

(i) **Emulsification of fat :** The fat globules are reduced in size and results a finer and more stable emulsions. Then the enzyme lipase can easily penitrate with each minute emulsified fat globule and increases the surface area and the velocity of enzyme action.

(ii) **Activating action :** The bile salts, by virtue of the cholic acid radical acts as a specific activator for all the enzymes in the intestine.

(iii) **Laxative action :** Bile salts irritate the small intestine and the nerve endings which cause the peristaltic movement of the intestine that is mass peristalsis performing laxative function.

(iv) **Neutralising action with the acid chyme :** Bile is alkaline in nature and regulation of bile in the stomach helps to neutralise gastric acidity and thus prevents the injurious effect of acids on gastric mucosa.

(v) **Carrier of Secretin :** It is secreted from the intestinal mucosa as pro-secretin and under the influence of acids, it converts into secretin which is carried by the bile salts.

(vi) **Hydrotropic action**: Bile salts act as solvents of fats, fatty acids and cholesterol in body fluids and by their hydrotropic action, serve as carriers of fatty acids and their esters.

(vii) **Cholagogue action**: Bile acts as its own stimulant and as a good cholagogue or direct cholagogue. It exerts a direct action to the liver cell after absorption from the intestine and helps for more and more flow of bile.

(viii) **Anti-septic Action**: Bile is said to be anti-putrifactive. It does not possess much bactericidal power but its anti-septic effect is supposed to be the laxative action of the bile salts which increases the process of peristalsis and thus allows less time for the bacteria to grow.

(ix) **Absorption of fat soluble Vitamins**: Bile salts helps in the process of absorption of all the fat soluble vitamins such as Vitamins A, D, E and K.

(x) **Lowering the surface tension**: Bile salts reduce the suface tension of the absorbing epithelium, increase their permeability and thus fascilitates the process of absorption.

(c) **Functions of Fatty acid**: (i) It forms lipide in combination with glycerol. (ii) It forms soap at the pH of 9. (iii) It combines with the bile salts to form fatty acid bile salt complex which ultimately form phospholipide. (iv) Fatty acid after oxidation forms acetic acid, acetoacetic acid and dicarboxylic acid.

(d) **Functions of Mucin**: (i) It protects the mucosa of the intestine from any sorts of injury. (ii) It lubricates the intestinal wall and helps to aid the movement of faeces. (iii) It maintains the pH of the blood. (iv) It serves as a buffer action.

(e) **Functions of Inorganic Salts**: (i) Sodium bicarbonate neutralises the excess of hydrochloric acid of gastric juice. (ii) Iron and calcium and to the mineral constituents of diet.

Circulation of Bile: The circulation of bile is broadly grouped into intra-hepatic add extra-hepatic circulation.

(a) **Intra-hepatic circulation**: Intra-cellular bile passages seen within each liver cell and these drain into bile passages called bile canaliculi. These lie between adjacent rows of liver cells alternating with the positions of sinusoids. Bile is not mixed with sinusoidal blood because they are separated by a row of liver cells Bile passages come out of the liver lobule as bile ductules running in the portal canal. These bile ductules unite and reunite to form two hepatic ducts which come cut through porta hepatis.

(b) **Extra-hepatic circulation :** The bile duct arises from cystic duct which after swelling forms gall-bladder. The blie duct unites with the pancreatic duct and forms common bile duct which forms a swollen structure known as ampulla of Vater just before entering into the second part of the duodenum. In the bile duct a sphincter is present which is known as sphincter of Boyden and there is an another sphincter situated in the common bile duct called sphincter of Oddi.

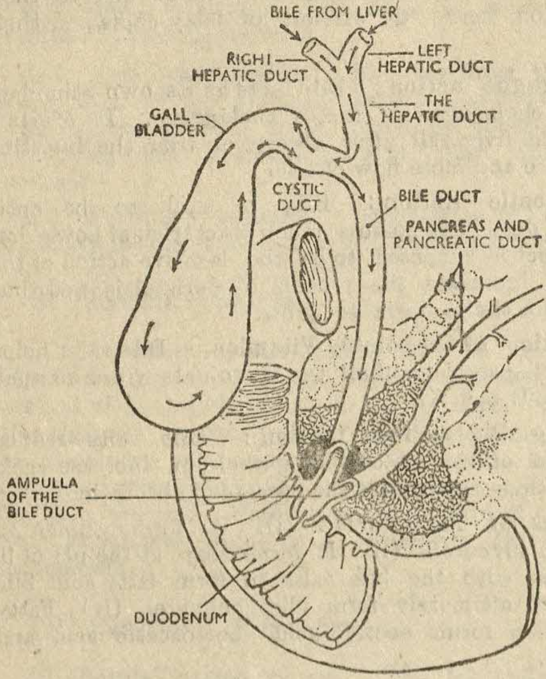


Fig. 25. Diagrammatic representation of Hepatobiliary structures showing the course of circulation of bile.

Q. 19. Describe the structure and function of Spleen. Discuss the Splenic Circulation.

The spleen is the largest ductless gland covered by a capsule which contains fibrous tissue and unstriped muscle. These plain muscle fibres contract at regular intervals, producing rhythmic variation in the volume of the spleen, in this manner blood may be squeezed out of the spleen and return to the liver. At the hilum, the arteries enter into it and the veins go out of it, surrounded by a fold of mesentry.

Anatomy : Spleen is an oblong, flattened form which is soft, of very friable consistency, highly vascular and of a dark purplish colour. In the adult, it is usually 12 cm. in length, 7 cm. in breadth and 3 or 4 cm. in thickness and weights about 200 gms, but it tends to diminish in size and weight with advancing age.

Histology : Spleen consists of Malpighian Corpuscles and the cells in the Splenic Pulp.

(A) **Malpighian Corpuscles** : The arteries pass in at the hilum surrounded by connective tissue and soon divide repeatedly, the smaller branches become surrounded by lymphoid tissue which swells out in places to constitute larger nodules, known as *Malpighian Corpuscle*. These are scattered uniformly through the substance of the organ and usually have a vessel in close relation to them.

(B) **Splenic Pulp** : It consists primarily of a network of fibres derived from the trabeculæ. It consists of red pulp and white pulp.

(a) **Red Pulp** : The cells found in the red pulp are of the following kinds : (1) Elements of the blood chiefly red cells and many lymphocytes. (2) Special cells of this pulp which consists of : (i) Large mononuclear cells which are amœboid and phagocytic and often contain red blood corpuscles. (ii) Branched reticulum cells which may possibly be of the same nature as the endothelial cells lining the venules. (iii) Giant cells which are more numerous in young animals and often contain ingested red cells.

(b) **White Pulp** : Smaller branches of splenic artery ultimately leave the trabecular sheath and here the adventitia of the vessels is replaced by a sheath of lymphatic tissue forming a network round the arterioles, called the *white pulp*.

Functions of the Spleen :

I. **Blood Formation** : (1) During the later months of foetal life, instead of emergency and in anaemia, spleen is actively engaged in forming red blood corpuscles. (2) The Malpighian corpuscles are merely nodules of lymphoid tissue and by their proliferation add to the number of lymphocytes in the circulating blood. (3) Monocytes are manufactured mainly in the spleen.

II. **Blood Destruction** : (1) The spleen is an important part of the reticulo-endothelial system and is actively concerned in the destruction of the old and worn out red blood corpuscles. (2) The cells of the pulp ingest and break down red blood corpuscles, remove the iron from the hæmoglobin which is then discharged into the blood.

III **Reservoir of Red Blood Corpuscles** : The spleen forms an important reservoir of red blood corpuscles which may be called on at times of emergency. (1) Oxygen lack or Anoexia, from any cause, causes the spleen to contract and diminish in volume of red blood corpuscles by carbon monoxide poisoning, as a result of haemorrhage, in exercise in rarified atmosphere and on prolonged exposure to raised external temperature. (2) The spleen is also contracted by certain anaesthetics e.g. ether and chloroform and by various operative procedure particularly those on the intestine, which lead to a splenic contraction lasting for days or weeks. (3) During oestrus and pregnancy in animals, the spleen is reduced in size to provide additional blood for the turgid generative organ and for the foetus.

IV. **Storage** : (1) Iron is stored in the spleen after the destruction of red cells and utilised for the manufacture of fresh haemoglobin. (2) Haemosiderin and detached reticulo-endothelial cells of the spleen are temporarily stored in the liver. (3) Many lipoids are stored in the spleen.

V. **Relation to Metabolism** : Lipoids are stored in the reticulum cells of the spleen, specially when the blood cholesterol is high as in Diabetes or after excessive ingestion of the substance. (2) Spleen is concerned with iron metabolism. The spleen stores up some quantity of iron out of the broken red blood corpuscles which is utilised later on according to the need. (3) Spleen is concerned with pigment metabolism. Haemoglobin is broken down and bilirubin is formed.

VI. **Defence Reactions** : (1) The spleen is supposed to be elaborating some antitoxins and antibodies, such as the haemolytic antibodies to prevent the destruction of the normal red blood cells (2) The reticulo-endothelial cells engulf bacteria, parasites and foreign bodies. (3) The lymphoid cells of spleen also reacts against infections.

Splenic Circulation : The splenic circulation starts form the *Splenic artery* which is a branch of coeliac artery. The splenic artery has a large calibre. tortuous in course, end arteries and diverse coat. It has got more branches known as *Trabecular arteries* which enter the hilum and ramify throughout its substances receiving sheath known as *Trabecular sheath*. The artery leaves the trabecular sheath and terminate in the proper substance of the spleen in small tufts or pencils of minute arterioles known as *Penicillar arterioles*. The arterioles are covered by lymphatic sheath from lymphatic nodules or

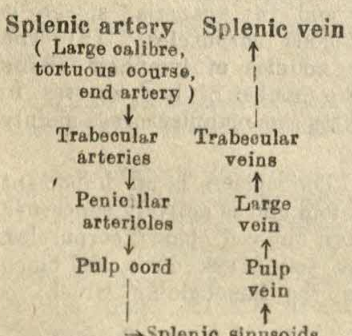


Fig. 26. Schematic representation of the course of circulation in Spleen.

Malpighian bodies or *white pulp*. The arterioles open freely into *splenic pulp* or *red pulp* which loose their tubular character. ramification of endothelial cells and their processes being directly connected with those of the reticular cells of the pulp. The connective tissue corpuscles of the pulp arrange themselves into rows and form elongated space or sinus known as *Splenic sinusoids*. The channel acquires a coat of ordinary connective tissue and lined with endothelial cell layer which is continuous with the supporting cells of the pulp. The channel obtains an external investment and converted into a small vein known as *Pulp vein*. The small veins unite to form *Larger veins* and not accompany with arteries. They enter the sheath of trabeculae of the capsule and form six or more vessels known as *Trabecular veins*. They emerge from the hilum, uniting and constitute *Splenic vein* which is the largest radicle of portal vein.

Q. 20. Describe the structure and function of Large Intestine.

Large intestine is the lowermost part of the gastro-intestinal tract developed from endodermal tissue, made up of four histological layers and serves the function of secretion of mucin, clearing of stool, absorption of water and formation of Vitamin K.

Physiologic Anatomy : (1) The large intestine is divided into different parts according to its position. The different parts are the ascending colon, transverse colon, pelvic colon etc. (2) The longitudinal muscle layer becomes specially connected into three bands called the taeniae coli. (3) The circular muscle becomes thickened at intervals giving rise to a series of pouch like dialatations containing a small lump of fat.

Physiologic Histology : (1) Histologically, the large intestine consists of four layers from outside inwards such as serous coat, muscular coat, submucous coat and mucous coat. (2) The mucous membrane is thrown into large folds containing numerous goblet cells that secrete mucin. (3) The glands are less in number and lined by coloumnar cells.

Functions of Large Intestine :

(a) **Absorptive functions** : (1) Large intestine absorbs 60% to 80% of water by the epithelial cells. (2) Normal saline is freely absorbed from the large intestine (3) Glucose absorbs at a very high rate by the large intestine. (4) Certain drugs like paraldehyde and alcohols are also absorbed to some extent by the large intestine.

(b) **Excretory functions** : Heavy metals like bismuth, mercury, arsenic etc, are excreted through the large gut.

(c) **Secretory functions**: (1) The goblet cells secrete mucin which acts as a lubricant. (2) Mechanical irritation stimulates some watery secretions.

(d) **Vitamin K formation**: Vitamin K is formed in the large intestine by the putrifaction of certain common intestinal flora done by non-pathogenic bacteria.

(e) **Movements of Large Intestine**: The large intestine possesses the following types of movements :

(i) **Peristalsis** : It is described to be a composite waves consisting of a wave of relaxation followed by a wave of constriction. It is a translatory movement and travels down the product of the gut in an aboral direction.

(ii) **Anti peristalsis** : It is a composite wave consisting of a wave of relaxation followed by a wave of contriction, but the food travels into the gut in an oral direction.

(iii) **Mass Peristalsis** : It is the chief movement of the large intestine. In usually starts in the right colic flexure. A strong rapid peristaltic wave passes along a transverse and descending colon and all the faecal matters are drained into the pelvic colon. These mevements are essential for the process of defaecation.

(iv) **Rhythmic Tonic Contraction** : It occurs from time to time throughout the length of the large gut. These movements do not propel the food in the gut onwards. It helps to maintain adequate circulation through the wall and also help in absorbing water by bringing the mucous membrane into a closer cotact with the contents.

(f) **Bacterial digestion** : Digestion by bacteria plays an important role in abnormal condition of stomach and small intestine. The unabsorbed food stuffs pass into the large intestine and are attacked by the bacteria. Then it forms a number of primary food stuffs such as carbohydrates, fats and proteins. The actual process of formation of those food stuffs are as follows : (i) **Carbohydrates** : When bacteria acts on carbohydrate, lactic acid fermentation takes place. (ii) **Fats** : When bacteria acts on fat, it forms lower fatty acids such as butyric acid, valeric acid, etc. and glycerol (iii) **Proteins** : When undigested protein act on bacteria, amino-acids and ammonia are formed. By the process of decarboxylation, amino-acids after bacterial action forms toxic amines.

Q. 21. Describe the Gastro-Intestinal Movements and discuss their importance.

The presence of muscular tissue in the alimentary canal indicates that some short of movements must be present in the gastro-intestinal tract. As a matter of fact the alimentary canal possess different parts and shows different types of movements. These sort movements are necessary to propel the food mass onwards, in order to bring it in contact with the different types or digestive juices and also for through mixing by which the process of digestion and absorption may proceed rapidly. It also helps for the process of defaecation.

Classification of the Gastro-Intestinal Movements : Functionally, there are two groups of movements which are given below : (a) **Translatory movements :** These type of movements travel onwards and propel the food mass, viz, peristalsis, antiperistalsis and mass peristalsis. (b) **Stationary movements :** These movements remain localised and do not move onwards viz, segmentation, tonic contraction etc.

Movements of the Alimentary Tract : The different types of movements of the alimentary tract are the following : (a) **Movements of the Stomach :** The different types of movements of the stomach are the cardiac sphincter, reception of food, mixing and emptying activity, movements of fasting stomach and vomiting. (b) **Movements of the Small intestine :** The different types of movements of the small intestine are peristalsis, antiperistalsis, pendular and segmentation. (c) **Movements of the large intestine :** The different types of movements of the large intestine are the peristalsis, anti-peristalsis and rhythmic variations of tone.

I. Movements of the Stomach :

(A) **Methods of Study :** A number of different methods have been used for studying gastric mobility. The various procedures used are radiological methods, test meal methods (Fractional Test-meal and Serial Test meal), Intra-gastric pressure study, etc.

(B) **Different Types of Movements :** The movements of the stomach can be divided into : (1) The control of the cardiac sphincter. (2) Movements concerned with reception of food. (3) Those concerned with mixing of the food with the gastric secretions and passing on the gastric contents to the duodenum. (4) Movements of the fasting stomach. (5) The abnormal emptying of the stomach through the œsophagus such as vomiting.

(a) **Control of the Cardiac Sphincter :** When food subtances are swallowed, they enter the stomach without any difficulty, but gastric contents do not usually regurgitate into the oesophagus due to the special mechanism of cardiac sphincter.

(b) **Reception of Food :** The gastric activities concerned with reception of swallowed food are the changes in tonus in the body and fundus of the stomach. The increasing in volume of gastric contents is not followed by a corresponding increase in pressure and the stomach is able to relax to receive the increasing volume.

(c) **Mixing and Emptying activities** : These depend primarily on the musculature of the antrum and pyloric region. The peristaltic movements soon begin to appear, when food is taken into the stomach. These are waves of contraction passing towards the pylorus preceeded by a wave of relaxation.

(d) **Movements of the Fasting Stomach** : The fasting contractions can only be recorded by balloon techniques. The possibility of fasting stomach movements depend on the presence of the balloon and do not represent a physiological process.

(e) **Vomiting** : Vomiting is the ejection of gastric contents through the oesophagus and mouth and is usually accompanied by a feeling of inetnse nausea and other autonomic disturbances such as pallor, sweating and acceleration of the heart rate.

II. Movements of the Small Intestine :

Methods of Study : The methods for analysing the movements include : (1) Direct inspections of the intestines at laparotomy. (2) Observation of movement of radio-opaque substances at different intervals after administration. (3) Measurement of pressure changes either by means of balloons or electric transducers. (4) Thiry-vella loop technique in animals. (5) Study in isolated intestine removed from an animal.

Types of Movements :

(A) Peristalsis :

(a) **Nature** : Peristalsis is described to be a composite wave, consisting of a wave of relaxation followed by a wave of constriction. It is a translatory movement travels down the gut in an aboral directions.

(b) **Rate of Propagation** : There are two types of peristalsis present in the small intestine. One type is a slow gentle wave moving at the rate of 1—2 cm. per minute but another type is a very swift wave travelling at the rate of 2—25 c.m. per second.

(c) **Functions** : (1) It helps in the propagation of the food onwards. (2) It serves the proper admixure of food stuffs with the digestive juices (3) It helps in the process of absorption by bringing the mucous membrane into closer contact with the food stuffs. (4) It increases vascular and lymphatic circulation through the wall of the gut.

(B) Anti-Peristalsis :

(a) **Nature :** It is a composite wave, consisting of a wave of relaxation followed by a wave of constriction. It moves in the oral direction. The anti-peristaltic movement is present in man on the second and third parts of the duodenum only but weak anti-peristalsis also occurs in the terminal part of the ilium.

(b) **Functions :** (1) It prevents a rapid passage of the ilial contents in o caecum. (2) It helps through admixture of food stuffs with digestive juices in the duodenum and casues duodenal regurgitation into the stomach

(C) Segmentation Movements :

(a) **Nature :** A length of small intestine becomes divided by a series of contrictions into a number of small segments which are ballooned at the centre. Each segment is then divided in its middle; and the previous constrictions disappear. This process occur about six times a minute.

(b) **Functions :** (1) It causes no forward movement of the intestinal contents. (2) It helps to mix the chyme with the intestinal juices and so aids digestion. (3) By bringing the chyme into intimate contact with the villi, it aids absorption. (4) It helps to squeeze blood and lymph out of the bowel and so aids their return to the thorax.

(D) Peudular Movement :

(a) **Nature :** The pendular movements were rhythmic lengthening and shortening of the intestine brought about by waves of contraction moving along the intestine in a downward or aboral direction. The movements are responsible for swaying side-to-side movements of the intestine They depend only on the muscle and were independent of the nerves.

(b) **Function :** Its purpose is to rearrange the intestinal coils within the limited space of the abdominal cavity.

III. Movements of Large Intestine :

Methods of Study : The different methods for analysing the movements of the large intestine include : (1) By radiographic studies using barium enemata introduced into the rectum (2) By percussion or auscultation of the abdominal wall, the movements of the fluid and gaseous contents produce audible sounds. (3) By direct inspection of the intestines at laparotomy. (4) By measuring pressure changes either by means of balloons or electric transducers. (5) By Thiry-vella loop technique in animals. (6) By studying an isolated intestine removed from an animal.

Types of Movements :

(A) **Rhythmic Variations of Tone :** It occurs from time to time throughout the whole of the large intestine. These movements do not propel the contents of the intestine onwards. The functions are : (1) It helps to maintain adequate circulation through the wall. (2) It also helps in absorbing water by getting the mucous membrane into a closer contact with the contents.

(*B*) **Peristalsis :** In the large intestine, there will be ill-defined peristaltic movement. It is a slow weak peristaltic movement and there will be alternate shortening and elongation in the transverse colon.

(C) **Anti-Peristalsis** : In man, it is sometimes seen in the ascending colon. It starts in the hepatic flexure and goes towards the caecum.

(D) **Mass-Peristalsis (Gastro-colic reflex) :** After each meal a gastro-colic reflex is set up. A brief, powerful peristalsis occurs in the colon, which constricts down and its contents are driven vigorously onwards. Due to this sort of large forward movement, the faeces reach the spelnic flexure, then the descending colon and finally the pelvic colon, where they accumulate. The faeces do not normally pass beyond the pelvi-rectal flexure. The normal rectum becomes empty except immediately before defaecation.

Q. 22. What do you know about Gastro-Intestinal Hormones ?

The hormones are the internal secretions of the endocrine glands. The gastro-intestinal hormones are the chemical substances that are liberated from the gastro-intestinal glands which are situated in the alimentary tract. These hormones help in the process of digestion and absorption of different food stuffs.

Gastro-Intestinal Hormones :

(a) **From Stomach** : Stomach liberates a number of digestive hormones known as *Gastrin*, *Enterogastrone* and *Urogastrone*.

(b) **From Pancreas** : The digestive hormones of the pancreas are the *Parcerozymin* and *Secretin*.

•(c) **From Liver** : Liver helps in the formation of a number of digestive hormones which are *Bile* and *Cholecystokinin*.

(d) **From Intestine** : There are a number of digestive hormones found in the intestine which are known as *Duocrinin*, *Villikrinin* and *Enterokrinin*.

Description of individual gastro-intestinal hormone :

(a) **Gastrin :** It was first discovered by *Edkins* in 1906 who suggested that a substance was liberated in the gastric mucosa which was absorbed into the blood stream and effected in the gastric gland. Gastrin I and gastrin II are the two pure forms of gastrin. They have been isolated from the antral portion of the gastric mucosa and are produced in the modified epithelial cells of the pyloric glandular mucosa. It helps in the copious flow of gastric juice that maintains proper digestion of protein and fatty food stuffs. It helps gastric mobility, to secrete pepsinogen and hydrochloric acid, bicarbonate containing fluid and enzymes.

(b) **Enterogastrone** : It was discovered by *Farre and Ivy* in 1926. This hormone is liberated in the duodenum on the entry of fat in the stomach. It is absorbed into the blood stream and when it arrives at the stomach, it inhibits the peristaltic movements and thereby the admixture of masticated food stuffs whith the digestive juices and the clearence of food stuff from oral to aboral side are enhanced,

(c) **Urogastrone** : This substance has been isolated from pregnant urine although it is also present in male urine. This is a polypeptide and may cause inhibition of gastric secretion.

(d) **Pancreozymin** : *Harper* and *Raper* in 1943 showed that pancreozymin was present in the mucosa of the upper instestine. This is a hormone which acts on the secretory cells and produces effects very like those of vagal stimulation. The secretory granules are broken down and a thick secretion rich in enzymes is produced.

(e) **Secretin** : It is discovered by *Bayliss* and *Starling* in 1902 who showed that by the action of acids, secretin is liberated from the duodenal mucosa. It is a watery secretion rich in salts but poor in enzymes. Secretin also has little effect on the zymogen granules in the cells. It stimulates the secretion of insulin from the islet cells of pancreas, helps to stimulate the adenylcyclase activity and lypolysis in the adipose tissues.

(f) **Bile** : Bile has got autoeffect over the liver cells by which more secretion and storage of bile take place from the liver cells and into the gall-bladder respectively.

(g) **Cholecytokinin** : This hormone is discovered by *Ivy* and *Oldberg* in 1928 in the duodenal mucosa by the presence of acids and fats. These substances when stimulate, expulsion of bile occurs which are called cholegogues. It also helps the secretion of bile and at that time it is known as choleretics.

(h) **Duocrinin** : It is discovered by *Grossman* and secreted from the duodenal mucosa which helps in the process of admixture of a number of digestive juices such as gastric, pancreatic and hepatic with the different food stuffs.

(i) **Villikrinin** : It is secreted from the epithelial cell of the villus of the small intestine that helps in the movements of the villus and thereby the process of fat absorption takes place very easily.

(j) **Enterokrinin** : It is discovered by *Nasset* in 1938 which is formed in the intestinal mucosa in response to food and when absorbed in the blood stream to affect other parts of the intestine. These hormone acts over the Lieberkuhn glands and helps for increased secretion of succus entericus.

Q. 23. Describe the process of absorption of Carbohydrates.

Absorption is a physico-chemical process by means of which digestive end products are transferred from the intestinal lumen into the blood vessels via intestinal epithelium. The end products of carbohydrate food stuffs such as glucose, fructose and galactose are absorbed in the blood from the intestinal lumen by the process of phosphorylation and phosphatase action, the chemical process invoiving the addition and removal of phosphate group to and from the hexose sugar during absorption.

Channels of Absorption : The channels of absorption of carbohydrates are done through portal vein and lacteal vessel. (*a*) **Portal Vein** : The digested end products of carbohydrates such as glucose, fructose and galactose lying in the intestinal lumen, is then absorbed by the intravillar vein via the surface epithelium of the villus and collected with the blood in portal vein by which the monosaccharides pass into the liver. (*b*) **Lacteal Vessel** : Very minute quantity of monosaccharides are absorbed by the central lacteal channel of the villus. Through the lacteal channels they appear in the lymph vessel and finally through the thoracic duct into the systemic circulation via heart.

Process of Absorption : It is an active process involving oxygen consumption and in anoxia the absorption is hampered. The digested end products of carbohydrate lying into the intestinal lumen then rest into the intervillar spaces of the villi of jejunal part of small intestine. A large part of this food stuff is diffused first into the surface epithelium by the process of phosphorylation. The intravillar veins then collect into a large portal vein which in its turn breaks into capillary in the liver. The monosaccharides are stored or metabolised there. The oxidised product appears as lactic acid which is also absorbed in the blood. The lateral movements of the villi and consequent upward movement of lacteal channel, the monosaccharide is absorbed in the lymph plexus. From there, the sugar is carried to the thoracic duct by the lymph vessels.

It must be remembered however that the greater part of the monosaccharide is absorbed through the portal channels and the lesser part through the lacteals. Modern conception relates to special bodies called "carriers" which can carry the glucose into the interior of the cells. These carriers when saturated naturally will limit the further absorption of glucose.

Rate of Absorption : The process of absorption of carbohydrate take place simply by diffusion. The glucose, fructose, galactose etc. diffuse through the membrane according to their molecular size. Galactose diffuses at a greater speed than glucose but fructose diffuses at a slower rate than glucose. The epithelial cell working as specialised laboratory chemist can identify the molecular structure and epimerisation of the different saccharides and allow necessary permit for entrance into the interior of the cells.

Change of Reaction during Absorption :

(1) Glucose from intestinal lumen enters into the surface epithelium by simply diffusion. In the epithelial cell, there are high energy phosphate, A. T. P., inorganic phosphoric acid and phosphorylase enzyme. The phosphate of A. T. P. combines with the glucose in presence of phosphorylase enzyme to form glucose—1—phosphate and it is then converted into glucose—6—phosphate. In this way, glucose is set free and it diffuses into the villar blood capillaries. (2) Galactose is similarly acted upon by A. T. P. to from galactose—6—phosphate within the surface epithelial cells. Galactose—6—phosphate is converted into glucose—6—phosphate by isomerase enzyme. When entering into the villar tissue fluid, the glucose—6—phosphate is again transformed into glucose by removal of phosphate by phosphatase. This glucose then diffuses through the capillary blood vessel membrane and mix with the blood. (3) Fructose combines with the A. T. P that is present in the epithelial cells of villus after it has been diffused through the cell membranes. By this process of phosphorylation, fructose—1—phosphate is formed which is then transformed into fructose—6—phosphate by mutase action. This fructose—6—phosphate is then converted into glucose—6—phosphate by isomerase enzyme. The phosphatase enzyme then removes the phosphate from glucose—6—phosphate to transform it into glucose which is then absorbed by the villar capillary blood vessels. These have been confirmed by administration of Phlorrizine and sodium monoiodoacetate which paralyse the phosphorylation process and depress the absoption of monosaccharides.

Q. 24. How Fat is absorbed in the body ?

The absorption of fat is a physico-chemical process by means of which the digested end products of fat, enter from the lumen of the intestine into the blood vessel through intestinal epithelium and to the lymph vessels through lacteal channels of the villus of small intestine. The physical process being the entrance of faty acid and glycerol molecules through the intestinal epithelium and the chemical process constitutes the reaction of different factor which help in the process of easy going of these elements as pseudoform fat molecules.

End Products of Fat Digestion : The end products of fat digestion are thus : (1) Mainly unhydrolysed, water soluble, neutral fats which under normal condition has ben reduced to a finely emulsified state. (2) Water soluble and diffusible fatty-acid-bile salt complex. (3) Monoglycerides and diglycerides, some soluble and some emulsified. (4) Glycerol which is water soluble and diffusible.

Factors for Fat Absorption :

(A) **Physical Factors :** The factors are : (1) **Movement of the Villus :** The hormone villikrinin stimulate directly the villi and it moves to and fro causing fat globules comes into the intra-villar spaces of the lumen and thereby absorption through the epithelial layer of the villi becomes easier. (2) **Movement of the lacteal channel :** Villikrinin indirectly stimulates the lacteal channels of the villi performing different sorts of movements of the villus that help the lymph vessels to come in contact with the fat globules. Thus the lacteal channels absorb fatty acids and glycerol.

(B) **Physiological Factors :** The factors are : (1) **Emulsification of fat :** The fat might be taken up from the lumen as fine emulsion which was of lipase, some bile salt and tryglyceride particles. (2) **Lowering of surface tension :** The bile salts when mix with the triglycerides or fatty acids, lowers the snrface tension of the fatty acid which causes the emulsified fat to be easily diffusible into the lymph. (3) **Hydrotropic action :** The fatty acids when combined with bile salts from a complex which is water soluble. These water soluble fatty acids dissolve in the lymph fluid. (4) **Activation of Enzymes :** The bile salts are responsible for the activation of enzymes. The lipase and phosphate enzymes are active in presence of bile and combined with the fatty acids and glycerol to form triglycerides of low molecular weight, which are easily diffusible. (5) **Cholagogue action :** Bile acts as its own stimuli and as a good cholagogue or direct cholagogue. It exerts a direct action to the liver cell after absorption from the intestine and thereby helps in the absorption of fat.

(C) **Biological Factors** : The factors are : (1) **Lining epithelium** : The lining epithelium of the villi consists of simple coloumnar type of cells which are arranged in a single layer. This epithelial layer is folded to form finger like projections called villi. The villi are 4 to 5 millions in number and are 0·5 to 0·7 m.m. in size. (2) **Absorbing surface** : The total absorbing surface in the intestine is 10 square meters. The whole length of the absorbing surface in covered with a single epithelial layer that are folded to form numerous villi. (3) **Time relation with absorption** : The digested end product remains in contact with the absorbing surface in a particular region for 4 to 6 hours. (4) **Amount of digested material** : The amount of digested end product varies according to intake of food and accordingly absorption time and absorption phase vary.

Process of Fat Absorption : The process of fat absorption can be discussed into three main phases :

(a) **Preparatory phase or Intra-luminar phase** : In this phase the fat molecules lie in the intestinal lumen, becomes finally digested to fatty acid and glycerol. The digested end products are ready to be absorbed by combining with bile, pancreatic juice and lipolytic enzymes.

(b) **Transport phase or Cellular phase** : The fine emulsion of fatty acid, triglycerides, bile salt complex then cross the epithelial layer of the villi. In the epithelial cells, the triglycerides combine with glycophosphoric acid to form phospholipid. The fat passes the cell layer with considerable modification and re-synthesis of triglycerides. Phosbholipids is formed but it is not an obligatory intermediate, although it facililates the passage of fat through the mucosal cell.

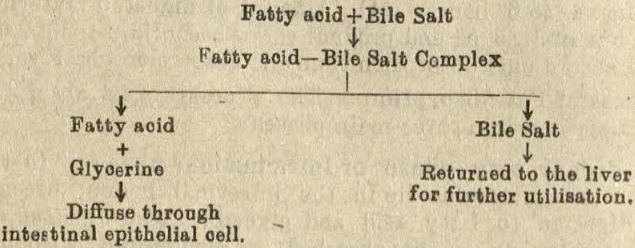
(c) **Distributive phase or Transportation phase** : In this phase the glycerides are removed from the mucosal cells of surface epithelium and are passed into the blood vessels and lymph channels. The lacteal channels are pushed upward by the lateral movement of the villi.

Theories concerning Fat Absorption : The mechanism of fat absorption in most cases is not strongly understood to-day. A number of theories have been presented over past fifty years but none of which has enjoyed universal acceptance.

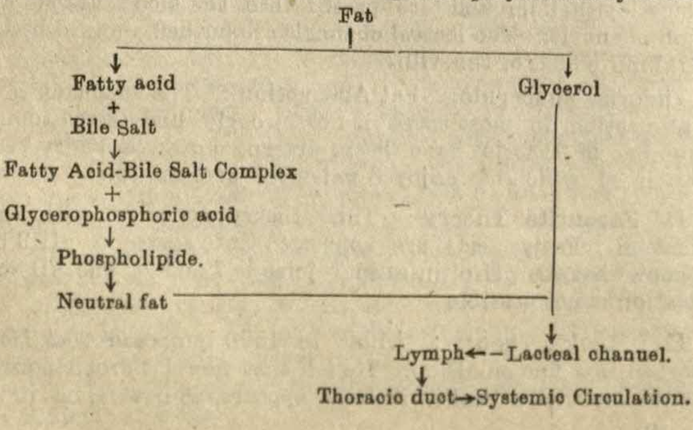
I. **Favourite Theory** : This theory concerns with soap formation. Fatty acids are converted into soaps at pH 9 but we know that the pH of intestinal juice is 7 and at this pH soap formation is not possible.

II. **Munk's Theory** : *Munk* in 1896 proposed that fat is absorbed as a fine emulsion. He felt that fine fat droplets might pass the epithelial walls, since it appears as neutral fat in the lymphatic system. He did not offer a good experimentation for the force which could bring the emulsified fat into lymphatics.

III. **Pfluger's Fatty-acid-bile salt complex Theory :** This theory concerns about fatty-acid bile salt complex. At first fatty acid combines with bile salt to form a complex which after diffusion through mucosal cells separates into fatty acids and bile salts. Fatty acids after combining with glycerine diffused through intestinal epithelial cells. Bile salts are returned to the liver for further use of it in complex formation. The schematic representation of Pfluger's fatty acid bile salt complex theory is thus :


Fatty acid+Bile Salt
Fatty acid—Bile Salt Complex
Fatty acid
+
Glycerine
Diffuse through intestinal epithelial cell.
Bile Salt
Returned to the liver for further utilisation.

IV. **Vergar's Lipolytic Theory :** *Verzar* and *Mc. Dougall* have established lipolytic theory in 1936. Their view about this theory of the formation of phospholipids from fatty acid-bile salt complex meets with Pfluger's theory. So this theory is also known as *Pfluger-Vergar lipolytic hypothesis.* Fat at first converts into fatty acids and glycerol after digestion. This fatty acid combines with bile salt and forms fatty acid-bile salt complex. This complex combines with glycerophosphoric acid and forms phospholipids, which again converts into neutral fat. This neutral fat enters into the lymph via lacteal channel and finally passes into the systemic circulation through thoracic duct The schematic representation of Vergar's lipolytic theory is thus :



V. **Frazer's Partition Theory** : This lipolytic theory was challenged by the partition theory of *Frazer* in 1946 according to which hydrolysis of fat was not a necessary preliminary to its absorption. In this theory, *Frazer* is able to show the fate of absorption of fatty acid and glycerol separately. The fatty acid is at first absorbed by the blood and passed into the liver through portal vein. The glycerol on the other hand is absorbed by the lymph through intestinal mucosa. The schematic representation of Frazer's partition theory is thus :

Fat

Faty acid
↓
Absorbed by blood vessels of villus of Intestine
↓
Enters into the Liver through Portal vein.

Glycerol
↓
Absorbed by intestinal mucosa
↓
Lacteal channels
↓
Lymph vessel.

VI. **Reiser's Theory** : His theory was established in 1952. Prepared synthetic triglycerides in which glrcerine was labelled with C.^{14} *Reiser* concluded that about half to one-third of ingested fat was hydrolysed to monoglyceride and the remainder was completely hydrolysed during digestion.

Q. 25. What is Normal Blood Sugar level ? What are the factors responsible for maintaining normal blood sugar level ? How it is Controlled ?

Sugar, as a form of glucose, fructose and galactose, formed due to carbohydrate digestion, enter into the blood vesels after absorption and go into the portal system and finally reaches into the liver. In the liver, all forms of glucose have been converted into glycogen by the process of glycogenesis and then the liver glycogen is again broken down into glucose by the process of glycogenolysis. This glucose after mixing with blood forms blood glucose. The normal range of blood glucose becomes 80 to 120 mgm. per 100 ml. of blood and the concentration of glucose is an important index of carbohydrate metabolism. Therefore, the normal blood sugar level represents the resultant of oxidation, storage and excretion on the one hand and absorption and formation of sugar on the other.

Factors for the Source of Income of Blood sugar : The different sources for entering glucose into the blood stream comes from : (1) The ingested carbohydrates. (2) From Proteins, Fats and Lactic acid by the process of neoglucogenesis. (3) From liver glycogen by the process of glucogenolysis. (4) Digestive absorption or sub-cutaneous or intravenous injection of glucose and glucose in the tissue fluids.

Factors for Expenditure of Blood Sugar: There are different ways by means of which blood sugar is utilised. The factors for expenditure of blood sugar are as follows: (1) Diffusion into the tissue fluids. (2) Storage of sugar as glycogen in the liver and muscle etc. (3) Conversion of glucose into fat. (4) Combustion of sugar in the tissues with the formation of carbon dioxide and water. (5) In certain cases such as in renal excretion. (6) Synthesis of lactose, glycolipids, nucleic acids and mucopolysaccharides. (7) Glycolysis by blood cells.

Regulation of Blood Sugar Level: The mechanism of blood sugar level involves the following factors:

I. **Hormonal Control:** The regulation of the blood sugar is acheived through the endocrine system and a number of different hormones are known to be concerned in this regulation. These include Insulin and glucagon, the hormones of the pancreas; adrenaline, produced by the adrenal medulla; the hormones of the adrenal cortex and the hormones of the anterior lobe of the pituitary.

(A) **Role of Pancreas:**

(a) **Influence of Insulin:** It is a strongest blood sugar reducing hormone, secreted from the β-cells of Islets of Langerhans. This hormone regulates the normal blood sugar level by inhibiting the process of neoglucogenesis, by stimulating the process of glycogenesis and stimulating the oxidation of glucose in the tissues by stimulating the enzyme system phosphorylase. It is said that rise in concentration of sugar in the blood evokes the secretion of Insulin.

(b) **Influence of Glucagon or Hyperglycaemic glycogenolytic factor or H-G factor:** The β-cells of the pancreatic Islets produce a water-soluble hyperglycaemic-glycogenolytic factor which regulates the blood sugar level by stimulating the process of glycogenolysis. Injection of this hormone may therefore produce hyperglycæmia which may lead to glycosuria.

(B) **Role of Pituitary Gland:** The connection between pituitary gland and blood sugar level was established by the classical experiment of *Houssay* and his colaborators from 1924 onwards.

(a) **Influcence of Diabetogenic hormone:** This hormone stimulates the process of glycogenolysis i.e., conversion of glycogen into glucose. It also stimulates the process of neoglucogenesis i.e., the formation of glucose from the sources other than carbohydrates and this hormone also inhibits the oxidation of glucose in the tissue by inhibiting phosphorylase enzyme system.

(b) **Influence of Growth hormone** : This hormone helps to increase the rate of growth of all growing cells of the body and thereby the rate of cellular mitosis is increased which seems to be due to increase rate of synthesis of all the individual cellular constituents.

(C) **Role of Thyroid Gland** : Thyroid gland liberates thyroxine that stimulates the process of glycogenolysis and also stimulates the process of neoglucogenesis. Injection of thyroxine to normal healthy individual will therefore produce hyperglycaemia that will lead to glycosuria when blood sugar level exceeds the renal threshold value. In hyperthyroidism, the blood sugar level will be high and in hypothyrodism, the blood sugar level will be low.

(D) **Role of Adrenal Cortex** : The adrenal cortex by its glucorticoid hormone, regulates the normal blood sugar level by stimulating the process of neoglucogenesis and by inhibiting the oxidation of glucose in tissue by the enzyme system hexokinase.

(E) **Role of Adrenal Medulla** : This gland produces adrenaline and nor-adrenaline which raise the blood sugar level by stimulating glycogenolysis and thereby blood suar level is raised in those conditions which leave to the release of adrenaline by the supra-reanl glands for example pain, fear, anger or asphyxia.

(F) **Role of Gonad** : Diabetes is a disease of old age, when gonads are hypoactive. The actual mode of a ction is not known, probably the hypoactive gonad fail to inhibit the anterior pituitary which then works unopposed and produces excess diabetogenic hormone.

II. **Nervous Control** : (1) The central nervous system plays an accessory rather than a major part in the processes of the normal blood sugar level. (2) Over actions on *hypothalamus* also cause prolonged hyperglycaemia and glycosuria. (3) The autonomic nervous system takes a greater part in blood sugar regulation.

III. **Visceral Control** : The control by different viscera about blood sugar regulation are :

(a) **Role of Small Intestine** : The carbohydrates are absorbed from the small intestine by active chemical process of phosphorylation. (b) **Role of Liver** : The liver in the intact animal maintains the normal level of the blood glucose by regulating the reversible reaction of blood glucose to liver glycogen, by regulating new glucose formation mainly from non-nitrogenous residues of amino-acids and by regulating the removal of glucose from the blood and its deposition as fat in the liver. (c) **Role of Kidney** : It helps in the reabsorption of glucose from the proximal tubules by the process of phosporylation and thereby regulates the normal blood sugar level. The maximum amount of glucose which can be reabsorbed back into the blood from the kidney tubule is known as renal threshold value for glucose. It is 180 mgm. per 100 ml. of blood. When the blood sugar level exceeds 180 mgm% the extra glucose will be excreted out with the urine and normal blood sugar level will be maintained. (d) **Role of Muscle :** Muscle draws in glucose from the blood stream and stores it as glycogen causing reduced blood sugar. In hypoglycaemia, lactic acid is mobilised from the muscles after severe muscular exercise, converted into sugar in the liver and discharge into the blood stream producing increaes blood sugar.

IV. **Physical Control :** It is done by dietary state, acidosis, tissue anoexia and starvation.

Q. 26. What do you mean by Biological Value of Proteins ? How it is determined ?

The biological value of protein is an expression of a number of the nutritional characteristics of the substance. Among these are the digestibility, the availability of the digested products and the presence an amounts of the various essential amino-acids. The values obtained for the nutritive or the biological value of a protein are emperical and are useful for comparing proteins from various sources or comparing a combination of protein such as might be found in a mixed feed or diet. The idea of the biological value of proteins provides a measure of the capacity of different proteins to maintain nitrogen equilibrium.

Methods of Determination :

I. **Mitchell's Nitrogen Retention Method** (Nitrogen Balance Method) : The technique of this method was developed by *H. H. Mitchell* and his many collaborators in 1924 at the University of Illinois. The nitrogen output in the faeces and urine is determined on a nitrogen free diet. The particular protein being examined, is now added to the diet and faecal and urinary output again determined. From this the absorbed nitrogen is calculated and compared with the nitrogen excreted in the urine in excess of that on a protein—free diet. This is the nitrogen wasted and the difference between this and the nitrogen absorbed gives the nitrogen retained.

II. **Growth Method :** *Osborn* and *Mendel* devised growth method in 1915 for the determination of the biological value of protein. This method involves the determination of the growth rate of young animals on a basal ration devoid of protein. The nutritive value of the protein is calculated as the ratio of gain in body weight to the weight of protein ingested during the experimental period—i e. gain in body weight in grams per grain of protein consumed.

III- Chemical Score Method of Block and Mitchell : *Block* and *Mitchell* in 1946 devised the chemical score method for the determination of the biological value of protein on the basis of amino-acid analysis. The chemical score depends on estimation of the amount of the essential amino-acids in a particular protein and comparing these with the idea provisional amino-acid pattern. The amount of each amino-acid is expressed as a percentage of the ideal and the lowest value found for any amino-acid is taken as the chemical score for the particular protein. The lowest value is taken because even one deficient amino-acid will make all the others less utilised.

Q. 27. Write Short Notes On :

(1) **Deglutition :** It is a phenomenon of masticatory process and the formation of bolus by mixing the saliva with the masticated food and the bolus is passed through the oesophagus and rest into the stomrch for proper digestion. **Process of Deglutition :** The act of deglutition divides into three stages by *Magendie*. (1) The first stage concerns about the masticated food which is collected as a bolus on the dorsum of the tongue that is pressed against the hard palate. Then the tongue is drawn backwards by different muscles. (2) The second stage comprises the food that enters into the pharynx and helps the food to pass into the oesophagus. (3) The third stage involves the passage of the food down the oesophagus. **Nervous Mechanism :** It comprises of centres, nerves and reflexes. (1) *Centres* : The deglutition centre is situated in the medulla oblongata. (2) *Nerves* : These are of afferent and efferent nerves. The afferent nerves are the trigeminal and glosso-pharyngeal nerve. The efferent nerves are the hypoglossal, trigeminal and glosso-pharyngeal nerves. (3) *Reflexes* : The reflexes concerning deglutition are of complete reflex act and the chain reflex.

(2) **Caseinogen :** It is a phosphoprotein and contains all the essential amino-acids necessary for the growth of the tissues **Digestive Products :** The caseinogen of milk is acted by Gastric Rennin and Chymotrypsin and forms proteose like substance and soluble caesin. The soluble caesin combines with ionised calcium and forms insoluble calcium caseinate which is known as curd. The curd is a protein which forms amino-acids after the activation of different types of protein splitting enzymes.

(3) **Colostrum :** It is the fromed milk secreted from the mammary gland of the female in the first three days after labour. *Composition* : It is very rich is proteins and salts. It contains large granular cells called colostrum corpuscles. *Properties* : It is thick and yellowish in colour. It is coagulated by heat or even spontaneously on standing. *Functions* : The colostrum acts as a purgative for the newborn baby. It is after

ingestion, helps to clear out the old intra-uterine faecal matter of the intestinal lumen to the exterior.

(4) **Ptyalin :** It is a carbohydrate splitting enzyme and it is also known as salivary amylase. *Formation* : It is liberated from the parotid gland which is situated in the buccal cavity. *Mode of Action* : It acts on boiled starch in slightly acid or neutral or slightly alkaline medium with an optimum temperature about 45°C. The boiled starch (100%) after activation of ptyalin, converts into maltose (80%) and the rest 20% converts into Isomaltose which resists for further action of ptyalin and ultimately excrete out through anal canal along with stool. The maltose is acted by maltase enzyme and converts into two molecules of glucose.

(5) **Trypsin :** It is a protein splitting enzyme and acts on alkali metaprotein and conveats upto polypeptide stage. *Formation* : It is secreted from the pancreatic cells of the pancreas in a form of inactive trypsinogen. It becomes active by the action of enterokinase which is present in the intestinal juice and it converts into active trypsin in alkaline media. *Mode of Action* : The alkali mixes with protein and forms alkali metaprotein. The active trypsin acts upon alkali meteprotein and breaks down upto polypeptide stage. The stages of breakdown of alkali metaprotein by active trypsin are : *Alkali Metaprotein→Primary Proteoses→Secondary Proteoses→Peptones→Polypeptides.* The active trypsin also acts upon peptone in acid side and breaks down into *Polypeptide stage.*

(6) **Lipase :** It is a fat splitting enzyme found in gastric, pancreatic and intestinal juices. *Different Lipases* : The different types of lipolytic enzymes are the Gastric lipase, Pancreatic lipase and Intestinal lipase. *Formation* : The gastric lipase is liberated from the stomach, the prncreatic lipase is secreted from the pancreas and the intestinal lipase is liberated from the small intestine. *Mode of Actions* : (i) The gastric lipase acts upon fat in acid media and breaks down into one molecule of glycerol and three molecules of fatty acids. (ii) The pancreatic lipase acts upon fat in alkaline media and breaks down into one molecule of glycerol and three molecules of fatty acids. (iii) The intestinal lipase acts upon fat in alkaline media and breaks down into one molecule of glycerol and three molecules of fatty acids.

(7) **Enterokinase** (*Enteropeptidase*) : It is an intestinal activator present in succus entericus and activates inactive trypsinogen into active trypsin. *Formation* : It is highly soluble and diffusible and is secreted from intestine *Mode of Action* : It exerts their action on inactive trypsinogen and forms active trysin which acts upon peptone and breaks down uptopolypeptide stage.

(8) **Secretin** : It is a digestive hormone found in the small intestine and helps in the secretion of more and more pancreatic juice. *History* : Secretin is discovered by Bayliss and Starling in 1902. *Formation* : Secretin can be extracted from the mucous membrane of the duodenum and upper part of the small intestine with water, HCl, soap solution or dilute alkali. *Properties* : It is believed to be a polypeptide, containing about 50 molecules of different amino-acids. Its molecular weight is about 5,000. It is rapidly destroyed by pepsin and trypsin in alkaline or neutral medium. It remains stable in acid solution. It is a watery secretion, rich in salts but poor in enzymes. *Function* : When secretin is injected intravenously, the increase flow of pancreatic juice takes place.

(9) **Bile Salts** : These are the main composite elements found in the bile which are liberated from the polyhedral cells and Kupffer cells of the liver. *Variety* : The bile salts are of two types which are known as Sodium taurocholate and Sodium glycocholate. *Chemistry* : These two bile salts are the sodium salts of taurocholic and glycocholic acids respectively. The taurocholic acid is formed by the combination of taurine and cholic acid. The glycocholic acid is formed by the union of glycine and cholic acid. Glycine is a simple amino-acid and taurine is derived from sulphur-containing amino-acid, cysteine. Cholic acid is a sterol compound which is the hydroxy derivatives of cholanic acid. *Synthesis* : All the components of bile-salts can be synthesised in the body, probably in the liver. The synthesis of bile acids takes place in the microsomal fraction of liver and involves ATP and Coenzyme A. Glycine can be synthesised in the body. Taurine is synthesised from sulphur-containing amino-acid, cysteine. Cholic acid can be synthesised from cholesterol. *Functions* : (i) It helps in the emulsification of fat and increases the velocity of enzyme action. (ii) It causes mass peristalsis performing laxative action. (iii) It helps in the neutralising action with the acid chyme. (iv) The pro-secretin converts into secretin which is carried by the bile salts. (v) The hydrotropic action modifies the permeability of the intestinal epithelium and fascilitates the absorption of the splitted fatty acids. (vi) It acts as a cholagogue action by which it helps for more and more flow of bile. (vii) It acts as an anti-septic action by which the process of peristalsis increases and thus allows less time for the bacteria to grow. (viii) It lowers the surface tension. *Fate* : Bile salts are mostly reabsorbed from the intestine and are re-excreted in the bile.

(10) **Hyperglycaemia** : It is a condition in which blood sugar level increases above the normal level i e , above 120 mgm. per 100 ml. *Manifestations* : (i) When the blood sugar level exceeds the renal threshold i.e. 180 mgm%., sugar appears in

the urine and forms glycosuria. (ii) There will be persistent hyperglycaemia due to diminished utilisation of glucose and discharge of excess sugar from the liver. (iii) Hyperglycaemia is caused due to hyper unction of some of the endocrine glands like anterior pituitary, adrenal cortex, etc. (iv) Diminished or lack of hyperglycaemia and glycosuria which are generally found in Diabetes Mellitus.

(11) **Hypoglycaemia** : It is a condition in which blood sugar level is present below the normal level i.e. below 80 mgm. per 100 ml. of blood. *Factors for Hypoglycaemic Symptoms* : (i) The actual blood sugar level. (ii) The rapidity of blood sugar reduction. (iii) The previous blood sugar level by which the tissues were accoustomed, *Manifestations* : (i) A feeling of fatigue, weakness and hunger. (ii) Extreme anxiety and irritability. (iii) Development of tremors and fine movements are not possible. (iv) Abnormal behaviour as in alcohol poisoning. (v) There will be vasomotor disturbances like flushing or palor, chilliness and perspiration. (vi) At last, there may be delirium, coma and convulsions and loss of deep reflexes.

(12) **Succus Entericus** : It is an intestinal juice secreted from the intestinal glands. *Enzymes Present* : Succus entericus contains protein splitting enzymes like active Erepsin, Nuclease, Nucleotidase, Nucleosidase, Arginase etc ; fat splitting enzymes like Intestinal lipase and carbohydrate splitting enzymes like Intestinal amylase, Maltase, Lactase, Sucrase etc. *Functions* : (i) The active erepsin acts upon alkali metaprotein and breaks down into amino-acid stage (ii) Nuclease acts upon nucleic acid in alkali media and breaks down into four mononucleotides. (ii) Arginase acts on arginine producing urea and ornithine. (iv) Intestinal lipase acts on fat and converts into one molecule of glycerol and three molecules of fatty acids. (v) Intestinal amylase acts on unboiled starch in alkali media and converts into stable dextrin and maltose. (vi) Maltase acts on maltose and breaks down into two molecules of glucose. (vii) Lactase acts on lactose and breaks down into one molecule of glucose and one molecule of galactose. (viii) Sucrase acts on sucrose and breaks down into one molecule of glucose and one molecule of fructose. (ix) The intestinal juice as a whole regulates normal body temperature, water balance, blood reaction, acid-base balance and excretory functions of mercury, lead, bismuth, arsenic, etc.

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CHAPTER FOUR

METABOLISM

Introduction : The metabolism of any substance is the fate of that substance after it has been absorbed into the blood. In this process, there are different types of chemical changes take place inside the organic tissue of the body. The chemical changes mainly are of two types known as synthetic and breakdown processes. These two processes are done by aerobic and anaerobic reactions.

The metabolism of *natural protein* is nothing but the fate of amino-acids after it has been absorbed into the blood. The final metabolised end product of it is the urea. The metabolism of

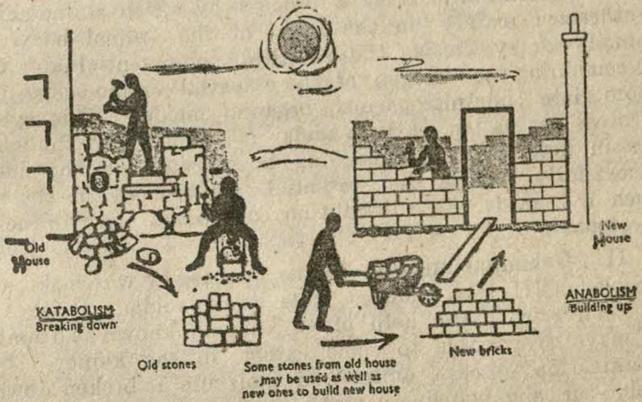


Fig. 26. Diagrammatic Representation of the process of Metabolism showing Katabolism and Anabolism.

nucleo-protein is nothing but the fate of nitrogenous bases (Purnie and Pyrimidine), pentose carbohydrate and protein. The final metabolised end products of them are uric acid and urea in man. The metabolism of *carbohydrate* is nothing but the fate of glucose, galactose and fructose after they have been absorbed into the blood. The final metabolised end products of them are Pyruvic acid and Lactic acid which finally convert into liver glycogen, muscle glycogen, carbon dioxide and water. The metabolism of *fat* is nothing but the fate of fatty acid and glycerol after they have been absorbed into the blood. The fate of fatty acid is the formation of acetic acid, aceto-acetic acid and di-carboxylic acid. The acetic acid converts into carbon dioxide and water. The other two products are excreted along with urine The glycerol converts into glycogen, first into liver glycogen and then into muscle glycogen which finally convert into carbon dioxide and water with liberation of energy.

Q. 1. Write what do you know about Amination, Deamination and Transamination.

The metabolism of amino-acids involves deamination and formation of the corresponding keto-acids preliminary to oxidation and the production of energy. The synthesis of amino-acids in tissues involves amination of keto acids derived from carbohydrate, protein and fat metabolism. The amino-groups of certain amino-acids may be transferred to the keto-acids corresponding to other amino-acids, therefore effecting amino-acid-keto-acid inter-conversion and this latter process is known as "*Transamination.*" The processes of deamination and amination are often inseparable, since amination may represent simply the reversion of deamination.

I. Amination : It is a process by which amino-acids are synthesized mainly in the liver of the animal body. The animals can synthesize the so-called non-essential amino-acids by combining the nitrogen of the essential amino-acids with the appropriate non-nitrogenous organic acids. This synthesis involves amination of keto-acids is indicated by the fact that certain keto-acids corresponding to essential aminoa-cids may successfully replace the essential amino-acids in the diets. Such a case is the substitution of indole pyruvic acid for tryptophan.

II. Deamination : It is the process by which the amino-radicle ($-NH_2$) is removed from amino-acids. It takes place in the liver with the help of an enzyme known as deaminase. It may be possible to some extent in the kidney. By the deamination process, amino-acid molecule is broken down into amino-part and non-amino part.

(A) Site of Deamination Process : (1) *Mann* and associates have shown that the liver is responsible for most of the deamination of amino-acids. (2) *Krebs* has studied the deamination of amino-acids by tissue slices and found that kidney and as well as liver are very active in the deamination process. (3) The various types of deamination process are discussed in reviews by *Cohen*, *Meister* and *Krebs*.

(B) Oxidative Deamination Process : *Krebs* found that kidney and liver of many animals contain enzymes which oxidatively liberate ammonia from amino-acids, approximately two molecules of NH_3 being formed for each molecule of O_2 taken up :

$$R.\ CH\ (NH_2).\ COOH + \tfrac{1}{2}\ O_2 \longrightarrow R.\ CO.\ COOH + NH_3.$$

(a) **Types of Oxidases :** (1) *Krebs* demonostrated the presence of D- and L-amino-acid oxidases which act upon D- and L-amino-acids respectively. (2) *Blanchard* and associates obtained from rat kidney and liver preparations of L-amino-acid oxidases. (3) The L-amino-acid oxidases of Kidney and Liver are also flavo-proteins but contain flavin mononucleotide (FMN).

(b) **Mechanism of Oxidative Deamination Process :**

(1) *By Flavoprotein Enzyme* : The amino-acids when combine with flavoprotein enzyme, forms Imino-acid which ultimately converts into Keto-acid.

Amino-acid + Flavoprotein Enzyme→Imino-acid + Reduced Enzyme.

Imino-acid + $H_2O \rightleftarrows$ Keto-acid + NH_3.

(2) *By Glutamic Acid* : The L-glutamic acid is deaminated by L-glutamic dehydrogenase which is widely distributed. The crystallised enzyme from beef liver contains Zinc.

L-Glutamic acid $\rightleftarrows$ α-Iminoglutaric acid + $H_2O \rightleftarrows$ α-Ketoglutaric acid.

In this reaction, either DPN or TPN may serve as co-factor.

(3) *By Glycine* : The glycine is deaminated by a specific glycine oxidase present in the Kidney and Liver of mammals and in bacteria.

Glycine + $\frac{1}{2}O_2 \longrightarrow$ Glyoxylic acid + NH_3.

(C) **Non-Oxidative Deamination Process:**

(a) *By Amino-acid dehydrogenases* : The hydroxy amino-acids serine, threonine and homoserine are deaminated by specific enzymes known as amino-acid dehydrogenases which catalyze a primary dehydration followed by spontaneous deamination.

$$\text{Serine} \xrightarrow{-H_2O} \underset{\text{compound}}{\text{Intermediate}} \longrightarrow \underset{\text{acid}}{\text{Imino}} \xrightarrow{\pm H_2O} \underset{\text{acid}}{\text{Pyruvic}} + NH_3.$$

The dehydrases require pyridoxal phosphate as co-factor.

(b) *By Amino-acid desulfhydrases* : The sulphur-containing amino-acids cysteine and homocysteine are deaminated by a primary desulfhydration forming an imino-acid which is then spontaneously hydrolyzed :

$$\text{Cysteine} \xrightarrow{-H_2S} \underset{\text{compound}}{\text{Intermediate}} \longleftrightarrow \underset{\text{acid}}{\text{Imino}} \xleftrightarrow{\pm H_2O} \underset{\text{acid}}{\text{Pyruvic}} + NH_3$$

The desulfhydrases require pyridoxal phosphate as co-factor which are found in Kidney, Pancreas, Liver and in some micro-organisms.

III. **Transamination (Reversibility)** : It is a process of combined deamination and amination according to which the amino-group of one amino-acid may be reversibly transferred to the keto-acid of another amino-acid thus effecting amino-acid-keto-acid interconversion. The process represents intermolecular transfer of amino-groups without the splitting out of ammonia. The reaction is reversible and is catalysed by transaminase enzymes which have been found in Heart, Brain, Kidney, Testicle, Liver, in higher plants and micro-organisms.

(a) **Process of Transamination :** (1) It was found that glutamic acid and its keto-acids, ∝-ketoglutaric acid participate in a large proportion of transaminations. (2) The highly purified preparations of glutamic-oxaloacetic and glutamic-pyruvic transaminase help in the process of transamination that requires pyridoxal phosphate as co-factor. (3) The glutamic-oxalo-acetic transaminase is the most active and widely distributed of the transaminases (4) The small contamination of a preparation with glutamic acid and a glutamic transaminase enzyme may catalyze the transmination of an amino-acid. (5) The glutamic acid and ∝-ketoglutamic acids are most commonly involved in transamination reactions, ∝-amino-monocarboxylic acids and ∝-keto-monocarboxylic acids may also transaminate. (6) The transamination reactions between glutamine or asparagine with keto-acids take place in which the amide group of glutamine or asparagine is split off by hydrolysis.

(b) **Mechanism of Transamination Process :** The Pyridoxamine phosphate has also been found to be effective as a co-factor in transaminations. *Snell* found that the transamination occurs in non-enzymatic model systems when Pyridoxal and Glutamic acid or Pyridoxamine and ∝-ketoglutaric acids are heated.

Q. 2. What is Urea ? How it is formed in the Liver ?

Urea is a carbamide and metabolised end product of protein and nucleo-protein. The deamination of amino-acid forms large amount of ammonia, which if allowed to accumulate in the body, would be highly toxic. In man and other animals, the detoxication is done by the liver and highly toxic ammonia will be converted into urea and uric acid is formed in replilés and birds. Urea was first discovered by *Rouelle* in 1773 and first synthesized by *Wohler* in 1828 by evaporating an aqueous solution of ammoninm cyanate.

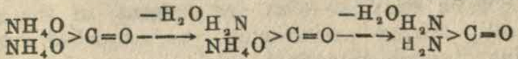
Site of Urea Formation : The site of urea formation was focussed in the past chiefly by lots of experiments known as perfusion experiment, tissue slice experiment and recent investigations, etc.

Mechanism of Urea Fromation : There are a number of theories come forward to show the mode of formation of urea in the body but none of them come into final conclusion.

I. Ammonia-Carbonate Method Theory : It has been assumed for a time that urea was formed from ammonia by the combination of ammonia with carbon dioxide and water to form ammonium carbonate and then, by loss of water molecule in two successive stages, the carbonate was changed first into carbamate and finally to form urea.

$$2NH_3 + H_2O + CO_2 \dashrightarrow (NH_4)_2\,CO_3$$

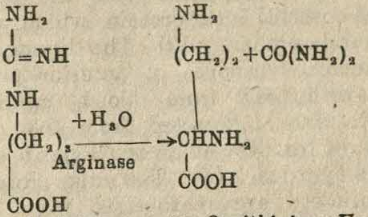
Amm. Carbanate.



$$\begin{matrix}NH_4O \\ NH_4O\end{matrix}\!>C=O \xrightarrow{-H_2O} \begin{matrix}H_2N \\ NH_4O\end{matrix}\!>C=O \xrightarrow{-H_2O} \begin{matrix}H_2N \\ H_2N\end{matrix}\!>C=O$$

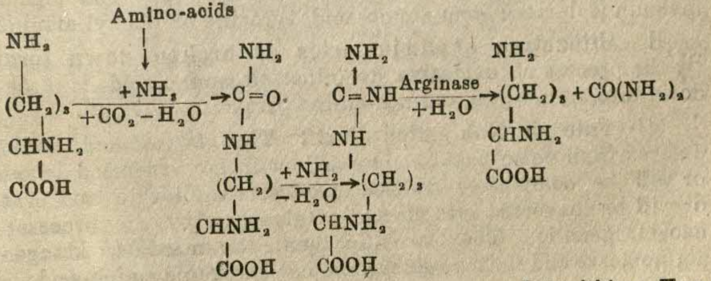
Ammonium Carbonate — Ammonium Carbamate — Urea

II. Arginine Method Theory : Urea was discovered in urine in 1773 by *Rouelle*, but the first indications of its metabolic source came from the experiment of *Kossel* and *Dakin* in 1904. They found that the enzyme arginase is present in many mammalian tissues specially in the liver which causes the hydrolytic cleavage of L-arginine to L-ornithine and urea.



L–Arginine L–Ornithinine Urea

III Krebs-Henseleit's Ornithine Cycle : *Krebs* and *Henseleit* in 1932 proposed a cyclic mechanism for urea synthesis involving ornithine, citrulline, arginine, ammonia and carbon dioxide.



L-Ornithine L-Citrulline L-Arginine L-Ornithine Urea

IV. Ratner's modification of Krebs-Henseleit Cycle : According to *Ratner* and associates in 1956, formation of ariginine from citrulline has been observed to take place in two steps :

(i) Condensation of citrulline with aspartic acid in presence of A. T. P. and Mg^{++} to form arginino-succinic acid.

(ii) Cleavage of arginino-succinic acid to arginine and fumaric acid.

Q. 3. Describe the fate of Amino-acids after absorption from intestine. What is Amino-acid pool ?

The ingested proteins are converted into amino-acids by the different proteolytic enzymes that are present in the gastro-intestinal tract. These amino-acids are absorbed from the small intestine through intestinal epithelium and reach into the liver via portal vein. After absorption, the amino-acids may be utilised in the system as an intact form and broken down form.

I. Utilization of Amino-acid as an Intact form : (1) Some of the amino-acids in the liver will conjugate together to give rise to plasma proteins which will circulate in the blood to maintain the plasma protein concentration in the blood. (2) The muscles will take amino-acids from the blood and these amino-acids will be coverted into protein which will be storee in the muscle as muscle pronein. (3) The hormones which ard protein in nature such as hormones of anterior pituitary gland insulin etc. are synthesised from blood amino-acids. The hormones like thyroxine is secreted from the thyroid gland and adrenalne secreted from the supra-renal gland are sythesised from the amino-acid tyrosine. (4) The milk proteins like lact albumin, lact globulin etc. are synthesised from blood amino-acids. It can be proved by finding the difference in concentrations of the amino-acids in between the arterial blood and the venous blood of the mammary gland and by using isotopic nitrogen in the amino-acid. (5) The taurine of sodium taurocholate and the glycol of sodium glycocholate are derived from the amino-acids cystine and glycine respectively. (6) The pigment melanin is derived from amino-acids tyrosine or phenyl alaninee.

II. Utilization of Amino-acids as broken down form : By the process of oxidative deamination, amino acid is broken down into amino-part and non-amino part.

(a) **Fate of Non-amino Part :** The fatty acid radical derived from deaminated amino-acids will be converted into fat or will be completely oxidised into carbon dioxide and water or will be converted into glucose or glycogen by the process of neoglucogenesis. They are glucogenic amino-acids, ketogenic amino-acids and neither glucogenic nor ketogenic amino-acids.

(b) **Fate of Amino-Part :** The amino-part of amino-acid is formed after deamination process, is required for the formation of urea. The actual mechanism of urea formation is discussed as follows :

Add *Mechanism of Urea Formation* (*Ques. No. 2*)

Amino-Acid Pool : The amino-acids are continuously being added to the body fluids by absorption from the intestine, synthesis and breakdown of tissue proteins. They are being removed continually for synthesis of tissue protein and other uses. The liver plays a special role as it not only synthesises its own protein but also the plasma proteins. Amino-acid are also withdrawn from the pool for deamination by the liver. This result in the formation of keto-acids and while some of these are oxidised, others are reaminated to form new amino-acids which are returned to the pool. As a result of this withdrawal and addition to the pool, there is a constant turnover both of amino-acids and of amino-groups in amino-acids.

Q. 4. Describe the metabolism of Creatine.

Creatine is methyl-guanidino-acetic acid which is widely distributed in animal tissues. The alkali favours the formation of creatine.

Distributions : Creatine occurs in greatest concentration in skeletal muscle, with lesser amounts in heart muscle, brain and pregnant uterus. In resting muscle, creatine exists largely as creatine phosphate. The total amount of creatine present in the muscle is 98% of the body. The skeletal muscle contains 0'5% creatine and the cardiac muscle contains 0 25% creatine. A very small amount of creatine is present in blood, about 0·2 to 0·6 mg% in plasma and about 3% in the body cell.

Origin and Formation of Creatine : The importance of creatine phosphate as a reservoir of high-energy phosphate readily convertible to A. T. P. muscles and other tissues. The synthesis of creatine involves the amino-acids glycine arginine and methionine. (a) *In the First Stage* : Guanidoacetic acid is first formed by a transamidination reaction between glycine and arginine, in which the amidine group of arginine is transferred to glycine. The transamidinase enzyme is found in mammalian kidney and pancreas but appears to be present in liver, heart, skeletal muscle, blood, brain and spleen. (b) *In the Second Stage* : Methionine is converted in to "active" methionie, S-adenosyl methionine, by A. T. P and the "methionine activating" enzyme and then guanidoacetic acid is methylated to creatine by S-adenosyl methionine and the enzyme "Guadino-acetic methylpherase". This stage takes place in the liver. The methyl group of creatine is not transferred to other compounds or not oxidised to formaldehyde or formate and consequently, does not contribute to the one-carbon pool.

Facts in support for the Origin of Creatine : (1) Administration of guanidine acetic acid (glycocyamine) increases creatine excretion like glycine or gelatin. (2) Glycocyamine is a normal constituent of tissues and urine. (3) Tissue slice experiments have shown that the kidney can synthesise glycocyamine from glycine and arginine and that liver can rapidly methylate glycocyamine when methionine is added. (4) Administration of N^{15}-lebelled glycocyamine to animals gave isotopic creatine. (5) N^{15}-lebelled glycine and arginine were the only labelled amino-acids which formed labelled creatine. (6) When the choline was fed deuterium in rats, was found in methionine and creatine.

Blood Creatine : The amount of creatine in blood becomes 10 mgm. per 100 ml. It is msstly present in the red cells. It is not filtered due to its presence inside the red cells. It is usually absent in the urine.

Fate of Ingested and Injected Creatine : (1) The oral and parenteral administration of creatine into animals or adult human males is followed by the excretion of only a fraction in the urine. (2) *Chanutin* and associates gave large amounts of creatine to rats and mice and found that the muscle creatine increased sharply for about a day, after which it remained practically constant. (3) *Bloch* and *Schoenheimer* showed that N^{15}-labelled creatine fed to rats has deposited in the tissues and its excretion indicates the origin of creatine. (4) *Hoberman* and associates have shown that the administration of the hormone methyltestosterone increases the rate of creatine synthesis in the body.

Functions of Creatine : (1) *It is concerned with utilisation of Metabolic energy* : Creatine phosphate is formed by transfer of the terminal high energy phosphate of A. T. P. to creatine, the A. T. P. being converted to A. D. P. The energy stored in this way can be utilised to reconvert A.T.P. when the need arises. (2) *It helps in the formation of Phosphagen* : Creatine is converted into creatine phosphate or phosphagen. It takes an essential role in the chemical changes during muscular contraction. (3) *It helps in the study of Renal function* : In children and in women, a certain amount of creatine appears in the urine and the reasons cannot be understood. (4) *It is the precursor of Creatinine* : Creatine acts as the precursor of creatinine.

Excretion of Creatine : Creatine is not a normal component of the urine but may appear in the urine in case of *creatinuria* by the following conditions :

(1) **Age :** It is constantly and normally present in children of both sexes upto the age of puberty. This fact may be associated with the low storage power of the muscles for creatine at an early stage Creatine is excreted irregularly by normal men.

(2) **Different periods in women** : (i) *After Puberty* : It is found in an intermittent manner in the urine of women, but it is not related to menstuation. (ii) *During Pregnancy* : There is a continuous creatine excretion during pregnancy. (iii) *After Parturition* : It rises to a maximum of 1·5 gm. daily after delivery, when it may be derived from the involuting uterus.

(3) **Sex** : (i) *After Pubery*, creatine is found in an intermittent manner in the urine of women. (ii) *In Eunuchs*, increased creatine is present in the urine producing creatinuria. (iii) *In old persons*, it may be easily induced due to diminished sex functions.

(4) **In unusual break of the Muscle** : In starvation, diabetes mellitus, exophthalmic goitre and fever, creatine is excreted in the urine.

(5) **Diet** : High protein and low carbohydrate diets increase creatine excretion due to stimulating tissue metabolism and by the absence of its sparing effects upon the breakdown of tissue protein respectively.

(6) **In certain pathological states of Muscle** ; In *Myopathies*, creatine is excreted because of the low storage power of the muscles. Even if only small amounts of creatine are ingested, 90% or more appears unchanged in the urine.

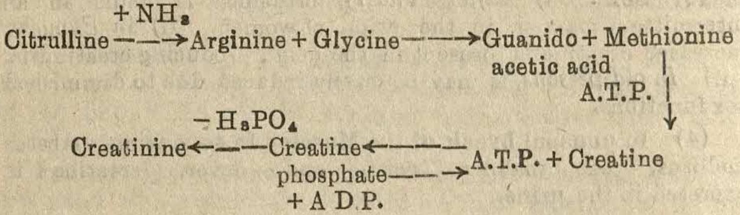
Defects in Creatine Metabolism : (1) Creatine occurs only in small amounts in the urine of normal adults. It is present, along with creatinine, during the process of growth and it decreases to very low values as maturity is approached. (2) *Creatinuria* is found in fevers, starvation, on a carbohydrate-free diet and in Diabetes mellitus. Its presence may be the result of excessive tissue destruction and liberation of creatine or failure under these conditions to keep the creatine properly phsophorylated, permitting the free creatine to diffuse from the tissues into the blood. (3) Excessive amounts of creatine may be excreted in the urine of patients with *Muscular dystrophy or Hyperthyroidism.*

Q. 5. Describe the metabolism of Creatinine.

Creatinine is the cyclic anhydride of creatine. The acid favours the formation of creatinine.

Distributions : Most of the creatinine formed in the body due to the spontaneous decomposition of creatine phosphate. The blood plasma contains about 0·6 to 1·0 mg% of creatinine and blood cell contains about 0·5 to 0·65 mg%. Creatinine is present in the muscle in much smaller amount. One hundred garms of skeletal muscle for example, contain 300 to 500 mg. of creatine and only 10 mg. of creatinine.

Origin and Formation of Creatinine : The formation of creatinine is as follows : Citrulline forms arginine with the addition of ammonia. The arginine combines with glycine forms guanido-acetic acid which after combination with Methionine forms creatine in addition with A.T.P. The creatine combines with A.T.P. forms creatine phosphate and A.D.P. The creatine phosphate with removal of phosphoric acid, forms creatinine.



$$\begin{tikzcd}
\text{Citrulline} \arrow[r, "+NH_3"] & \text{Arginine + Glycine} \arrow[r] & \text{Guanido acetic acid + Methionine} \arrow[d, "A.T.P."] \\
\text{Creatinine} & \text{Creatine phosphate + A.D.P.} \arrow[l, "-H_3PO_4"'] \arrow[r, shift right] & \text{A.T.P. + Creatine} \arrow[l, shift right]
\end{tikzcd}$$

Facts in support for the Origin of Creatinine : (1) Administration of N^{15}-labelled glycocyamine to animals gave isotopic creatinine. (2) N^{15}-labelled glycine and arginine were the only labelled amino-acids which formed labelled creatinine. (3) When the methionine was given to rats deuterium was found in choline and creatinine.

Blood Creatinine : The amount of creatinine in the blood becomes about 0·7 to 2·0 mgm. per 100 ml. The blood creatinine level is very constant. If this level becomes above 2 mgm., it is generally considered to be pathological.

Fate of Ingested and Injected Creatinine : (1) *Bloch* and *Schoenheimer* showed that the urinary creatinine excreted, contained amounts of N^{15}-indicating its origin from creatine. (2) They gave isotopic creatinine N^{15}-to rats and found 75% of the N^{15}-in urinary creatinine. The remaining 25% could not be accounted for in either tissues or urine.

Functions of Creatinine : (1) *It helps in the study of Renal functions :* The endogenous creatinine production is sometimes used for the study of renal function which is the significance of endogenous creatinine clearance test. (2) *It is an index of Endogenous and Exogenous metabolism :* At one time, creatinine excretion was used as an index of so-called endogenous metabolism. This derived from the fact that its excretion in the urine did not vary with the diet, as did excretion of urea, which was regarded as an index of exogenous metabolism.

Excretion of Creatinine : (1) *Excretion of Endogenous Creatinine :* Creatinine is formed in the body exclusively from creatine via creatine phosphate. A minute amounts of endogenous creatinine are present in blood (1 mg. per 100 ml). It is a non-threshold substance which is excreted in the urine by filtration from the glomeruli. (2) *Urinary Output of Creatinine* : The urinary output of creatinine during a period of work is invariable greater than during the corresponding time of a day of inactivity. The daily output of creatinine is about 1·2 to 2·0 gm. in adult males and 0·8 to 1·5 gm in adult females. They are reasonably constant and is independent of the protein intake or the total amount of nitrogen excreted. (3) *Product of Endogenous Metabolism* : It represents the removal of the steadily expendable creatine. The excretion of creatinine means the loss of valuable methyl groups from the body which is replaced from methionine.

Q. 6. Describe the metabolism of Tyrosine and Phenylalanine.

Phenylalanine is an essential amino-acid in mammals while tyrosine is formed from phenylalanine which is not an essential amino-acid. These two amino-acids are probably related metabolically. The feeding of tyrosine decreases the need for phenylalanine by reducing the quantity of phenylalanine converted to tyrosine. The deamination product of phenylalanine, phenylpyruvic acid, may replace pnenylalanine in the diet indicating its reamination to phenylalanine.

Metabolic Pathway of Phenylalanine and Tyrosine : In the metabolism of phenylalanine, the amino-acid is first irreversibly hydroxylated to tyrosine and then tyrosine undergoes a series of changes leading through p-Hydroxyphenyl pyruvic acid, Homogentisic acid, Maleylaceto-acetic acid and Fumarylaceto-acetic acid to fumaric acid and aceto-acetic acid. Fumaric acid, being a component of the citric acid cycle, is convertible through pyruvic acid to glucose and glycogen. The ketone body, aceto-acetic acid, goes the pathway of fatty acid metabolism, being convertible into acetyl CO A. Thus, phenylalanine and tyrosine are both glycogenic and ketogenic.

The conversion of phenylalanine to tyrosine represents a complex process involving an enzyme system commonly called "phenylalanine oxidase" but which in reality, is composed of two enzymes. The over-all reaction is generally represented as follows :

$$\text{L-Phenylalanine} + \text{TPN H} + \text{H}^+ + \text{O}_2 \longrightarrow \text{L-Tyrosine} + \text{H}_2\text{O} + \text{TPN}^+$$

Latest Opinion about Phenylalanine and Tyrosine Metabolism : Recent work of *Kaufman and Levenberg* has shown that tetrahydrofolic acid or tetrahydro-pteroylglutamic acid and other tetrahydropteridines, such as 2-amino-4-hydroxy-6 methyl-tetrahydropteridine, may serve as co-factor in the hydroxylation though the natural co-factor has not been identified. It appears that the hyproxylation involves two reactions which may be represented as :

$$\text{(1) L-Phenylalanine} + O_2 + \text{Tetrahydropteridine} \xrightarrow{\text{Enzyme 1}} \text{Tyrosine} + H_2O + \text{Oxidised Pteridine.}$$

$$\text{(2) Oxidised Pteridine} + \text{TPN H} + H^+ \xrightarrow{\text{Enzyme 2}} \text{Tetrahydropteridine} + \text{TPN}^+$$

Formation of Different Products from Phenylalanine and Tyrosine : There are a number of products formed from tyrosine which are discussed as follows :

(1) *Formation of Epinephrine (Adrenaline) and Norepinephrine (Arterenol)* : The synthesis of epinephrine and norepinephrine in the adrenal medulla from tyrosine proceeds through 3,4-dihydroxy phenylalanine (dopa) and 3 4-dihydroxy phenylethylamine (hydroxytyramine), both of which have been found in extracts of the adrenal gland.

(2) *Formation of Thyroxine* : Thyroxine, the active hormone of the Thyroid gland, occurs as a part of the thyroglobulin molecule along with diiodo-tyrosine When radio-active Iodine as Inorganic iodide is given to animals, it is rapidly incorporated into the thyroglobulin of the thyroid gland, first as diiodotyrosine and later as thyroxine.

(3) *Formation of Tyramine* : It is formed in the alimentary tract by the action of micro-organisms. It is formed from tyrosine by the process of decarboxylation. *Schuler* and associates showed that tyrosine is formed by the action of kidney slices upon tyrosine. The reaction is favoured by oxygen deficiency. In the presence of sufficient oxygen the tissue deaminated tyrosine instead Tyramine and related amines elevate blood pressure.

(4) *Formation of Melanin* : Melanins represent the dark pigments of skin and hair and are formed from 3, 4 dihydroxy phenylalanine (dopa) through a complex series of reactions. While the melanins of human beings are derived from tyrosine through dopa, most polyhydroxyphenyl and aminophenyl compounds having ortho or para groups can be oxidised to pigmented polymers and the type of melanin is best shown by indicating the substance from which the melanin is formed. Thus we may have dopa melanin, adrenaline-melanin, homogentisic acid-melanin, P-phenylenediamine-melanin etc. Melanin forms a reversible oxidation-reduction system, in which the reduced form is tan and the oxidised form is black.

Micro-bial Synthesis of Phenylalanine and Tyrosine of Aromatic Amino-acids: While mammals are unable to synthesize phenylalanine, various micro-organisms such as *Neurospora, E. coli* and *A. aerogens* synthesize both phenyl alanine and tyrosine, the amino-acids being derived from a common precursor, phrenic acid.

Fate of Tyrosine by Intestinal Bacteria: Tyrosine when acted upon by intestinal bacteria, forms phenol by the following ways: Tyrosine after *deamination* forms p-hydroxyphenyl propionic acid which after *decarboxylation* and *oxidation*, forms p hydroxyphenyl acetic acid. It again forms into p-cresol after *decarboxylation* and again after *demethylation* forms phenol.

Fate of Phenylalanine by Intestinal Bacteria: Phenylalanine when acted upon by intestinal bacteria, forms phenol and acetic acid by the following mechanisms: Phenylalanine after *deamination*, forms Phenylpropionic acid which after *decarboxylation* and *oxidation*, forms Phenylacetic acid. It forms into phenol and acetic acid by *hydrolysis*.

Fate of Phenylalanine and Tyrosine after normal absorption: Tyrosine and phenylalanine after their normal absorption, undergo the following changes: (a) *In the Adrenal Cortex and Medulla*: The above two amino-acids are at first converted into di-hydroxy phenylalanine (DOPA) and then into adrenaline. (b) *In Thyroid gland*: They act as the precursors from which thyroxine is manufactured. (c) *In the skin, choroid, hair etc*: In these conditions, the enzyme tyrosinase act upon tyrosine and corvert it into melanin.

Hereditary Defects in Phenylalanine and Tyrosine Metabolism: There are a number of well established hereditary defects in the metabolism of phenylalanine and tyrosine through the main pathway are *Alcaptonuria, Tyrosinosis, Phenylketonuria* or *Phenylpyruvic oligophrenia* and *Albinism*.

(a) **Alcaptonuria:** It is an inborn error of phenylalanine and tyrosine metabolism first described by *Bodeker* in 1858. It is characterised by the excretion of urine which upon standing gradually becomes darker in colour and may finally turn black. It is due to the formation of 2, 5—dihydroxyphenyl acetic acid or homogentisic acid. This condition is hereditary and more frequent in males than in females. It shows a familial tendency and is inherited as a recessive Mendelian character.

(b) **Tyrosinosis:** It was first desribed by *Medes* in 1932 and two other cases have been found by *Felix* and associates. It is characterised by excretion in the urine of tyrosine, p-hydroxyphenylpyruvic acid and p-hydroxyphenyllactic acids and small amounts of 3, 4—dihydroxyphenyl pyruvic acid, the deamination product of tyrosine.

(c) **Phenylketonuria** (Phenlpyruvic oligophneria) : It is characterised by inferior mental ability and excretion in the urine of phenylpyruvic acid and excessive amounts of phenylalanine with small quantities of phenyl lactic acid.

(d) **Albinism** : The black pigment melanin found in the retina, hair and sunburnt skin of white races and dark skin of coloured races is probably produced by oxidation of tyrosine has been worked out in detail by *Raper*, who showed that the oxidation involves the formation of dihydroxyindole, which polymerises spontaneously to melanin.

Q. 7. What is Nucleo-protein ? Write down the metabolism of Nucleo-protein.

The nucleoproteins are present in the cell and specially in the nuclei. They play an indispensible role in the living tissues and take part in the synthesis of all proteins. The phenomenon of heredity are closely connected with the properties of nucleoproteins. Nucleoproteins are formed by the combination of nucleic acid with a protein which is usually a histone or protamine. Nucleic acids consist of phosphoric acid, purines, pyrimidines and pentose sugars.

The nucleic acids are of two types such as deoxyribo-nucleic acid or D. N. A. and ribo-nucleic acid or R.N.A. The cell nuclei coniains D.N.A. but R.N.A. is present mostly in the cytoplasm. The pentose carbohydrates present in R.NA. is β-D-ribofuranose and in D.N.A is β-D-deoxyribofuranose.

End Products of Nucleo-protein digestion : The nucleoprotein is spilt up into nucleic acid and protein by nucleo-protein splitting enzymes such as Pepsin and Trypsin. The specific tissue enzymes known as *dexoyribonuclease* and *ribnuclease* that break the respective nucleic acid molecule into smaller groups of nucleotides—*oligonucleotides* and *tetra-nucleotides*. These enzymes are present in the pancreas and other animal tissues, in yeast and in cartain bacteria. This nucleic acid after splitting, forms phosphoric acid, pentoses sugar, purine and pyrimidine bases. So, the end products of nucleo-protein after digestion are protein, pentose sugar, phosphoric acid and the nitrogenous bases like adenosine, guanosine, uridine, cytodine and inositol.

Fate of digestive end products of Nucleo-protein after absorption :

I. **Fate of Protein :** The protein belongs to histone group is acted on by active pepsin and hydrochloric acid and are converted into peptone stage. The peptone in the small intestine is acted on by the enzymes trypsin and erepsin and is finally converted into amino-acids.

II. **Fate of Phosphoric acid :** It is attached with adenosine di-phosphate and forms adenosine triphosphate with the help of an enzyme phosphatase by the phosphorelization process. By this process, phosphoric acid starts to release chemical energy.

III. **Fate of Pentose sugar** : The pentose compound is formed in the body in the formation of nuclear structure such as Ribonucleic acid in thh body.

IV. **Metaboliam of Purine Base :**

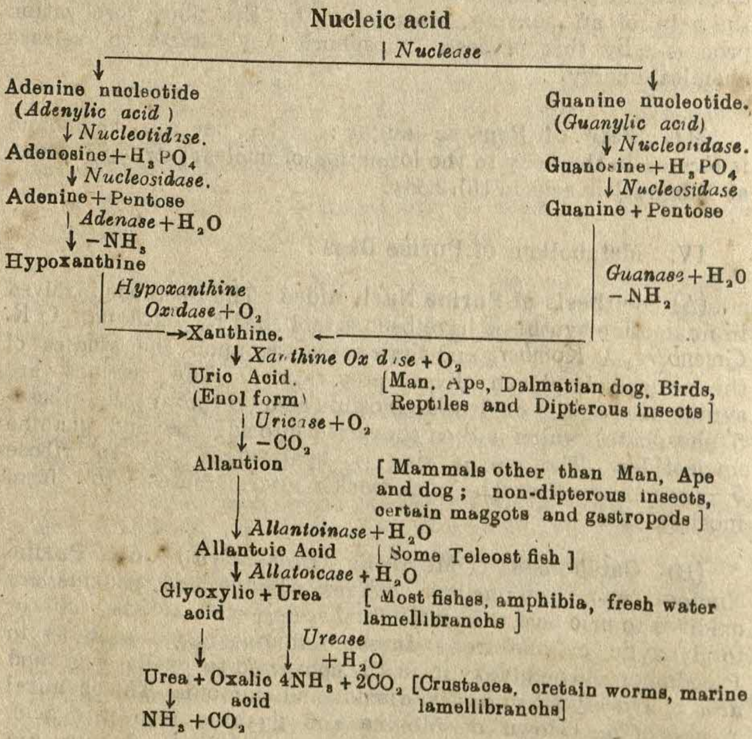
(A) **Synthesis of Purine Nucleotides** : The reactions involved in nucleotide synthesis have been established by *Buchanan*, G.R. *Greenberg*, A. *Komberg* and their associates upon the studies of the action of pigeon liver preparations. The purines are synthesized as the nucleotide inosinic acid (Hypoxanthine-ribose-5′-phosphate), which is then converted into adenine and guanine nucleotides. The purine ring is synthesized on to ribose 5—phosphate through numerous intermediates to form inosinic acid.

(B) **Catabolism** (Metabolic Breakdown) **of Purine Nucleotides :** The purines such as adenine and guanine are oxidised to uric acid or may be further degarded to allantoin or to glyoxylic acid and urea. In some microganisms such as in Pseudomonas, the glyoxylic acid is converted to oxalic acid and urea is hydrolysed to carbon dioxide and ammonia. The chemical process of breakdown of adenine and guanine into uric acid, allantion, glyoxylic acid, urea, carbon dioxide and urea are shown in a schematic form in Fig. 27.

V. **Metabolism of Pyrimidine Base** :

(A) **Synthesis of Pyrimidine Nucleotides** : *Buchanan* and *Wilson* have reviewed the status of this problem and *Komberg* and associates have recently contributed to the reaction mechanisms involved. It appears that oxaloacetic acid, aspartic acid, ureidosuccinic acid, dihydroorotic acid and orotic acid forms uracil with the elimination of carbondioxide. Uracil, by amination at position 6, forms Cytosine (2-oxy-6-aminopurine) and methylation of uracil at position 5, foorms Thymine (5-methyl uracil).

(B) **Catabolism of Pyrimidine Nucleotides :** Pyrimidine nitrogen is largely excreted in the urine as urea and ammonia. This indicates complete disruption of the pyrimidine ring. The uracil and thymine are degraded in animals by similar pathways involving :



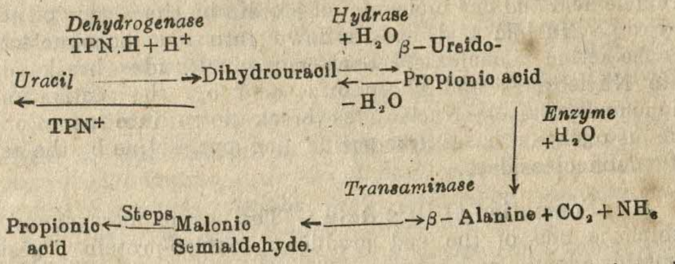
Fig, 27. Schematic representation of the metabolic breakdown of Nucleic Acid.

(i) Reduction of the pyrimidine ring to a dihydropyrimidine, as in the dihydro-orotic dehydrogenase-catalysed reaction.

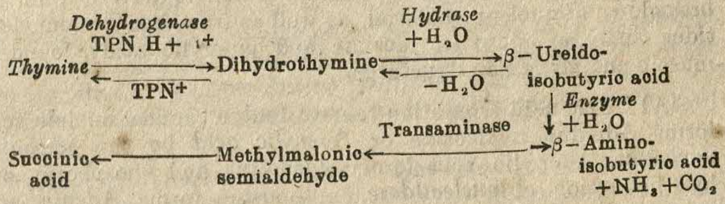
(ii) Opening of the ring to form β—ureidopropionic acid (from uracil) or β-ureidoisobutyric acid (from thymine), as in the dehydoorotase reaction.

(iii) Decomposition of ureido compnund to form CO_2, NH_3, and β alanine (from uracil) or β-amino-isobutyric acid (from thymine).

(a) **Fate of Uracil :** It finally forms propionic acid through successive stages which are as follows :



(b) **Fate of Thymine :** It finally forms succinic acid though successive stages of breakdown which are as follows :



Q 8. What is Uric acid ? How it is formed in the body ?

Uric acid is the final end product of purine metabolism in man and is excreted in urine of about 0·5 gm. to 1 gm. per 24 hours but the amount is subject to wide variation, particularly under certain dietary and pathological conditions. It is a transparent crytalline powder, practically insoluble in cold water, sparingly soluble in hot water, easily soluble in alkalies, alkali carbonates, boiling glycerol, concentrated sulphuric acid and in certain organic bases such as ethylamine and piperidine. Is is insoluble in alcohol and ether in pure state found in normal human urine, human blood (increased in amount in Gout, Nephritis and Lead-poisoning), also occurs to a much larger extent in the excrements of birds and reptiles. It was first discovered by *Scheele* in urinary calculi in 1776. Uric acid after heating, decomposed into urea, cyanuric acid, hydrocyanic acid and ammonium carbonate.

The uric acid content of the urine is of importance in relation to the farmation of uric acid calculi. The administration of alkali carbonates and cirates, by decreasing the acidity of the urine, increases its solvent power for uric acid and decreases the liability of formation of this type of calculi.

I. **Formation of Purine Base :** The nucleo-protein breaks down into nuclein and one molecule of protein by the activation of active pepsin in acid media. Nuclein breaks down into Nucleic acid and one molecule of protein by the action of active trypsin. Nucleic acid breaks down into four mononucleotides by the action of nuclease. Each mononucleotides breaks down into Nucleosides and phosphoric acid by the activation of mononucleotidase. Nucleosides break down into pentose and the nitrogenous bases like purine and pyrimidine by the action of mononucleosidase.

II. **Formation of Uric Acid :** The purine nitrogenous base which is one of the end product of nucleo-protein digestion, contains adenine and guanine. These are in turn forms uric acid in man from their own metabolic breakdown. The endogenous uric acid is formed from body purines which is derived from the breakdown of nuclear material as well as from free mononucleotides such as adenylic, inosinic and guanylic acids, found in muscle and glandular structures.

(A) **Uric acid fromation from Adenine :** The nucleic acid forms Adenine nucleotide or *Adenylic acid* by the action of *nuclease*. Adenylic acid forms *Adenosine* and phosphoric acid by the action of *nucleotidase*. Adenosine forms *Adenine* and pentose by the activation of *Nucleosidase*. Adenine, is deaminated by a specific tissue enzyme, *adenase* to form *Hypoxanthine*. Hypoxanthine is then oxidised by *hypoxanthine oxidase* to form *Xanthine*. Xanthine is then further oxidised by means of *Xanthine oxidase* to form uric acid, which is found in man, ape, dalmatian dog, birds, reptiles and dipterous insects.

(B) **Uric acid formation from Guanine :** The nucleic acid forms Guanine nucleotide or *Guanylic acid* by the action of *nuclease*. Guanylic acid forms *Guanosine* and phosphoric acid by the action of *nucleotidase*. Guanosine forms *Guanine* and by a specific tissue enzyme *Guanase* to form *Xanthine* Xanthine is then further oxidised by means of *Xanthine oxidase* to form uric acid which is found in man, ape, birds, reptiles etc.

Q. 9. Describe how Carbohydrate is metabolised in the body. What is Glucose Pool ?

The metabolism of carbohydrate in the body is essentially the series of changes undergone by glucose and glycogen and to a much smaller extent by fructose and glactose. Most of the carbohydrate present in the body is in the form of glycogen that is chiefly present in the muscle and liver. So, glycogen is therefore the main store of carbohydrate in the circulating blood, helps in the study of carbohydrate metabolism in health or disease. The glucose concentration in the circulating blood signifies a starting point for consideration of carbohydrate metabolism.

End products of Carbohydrate digestion : The polysaccharides and disaccharides form of carbohydrate are converted into simple monosaccharides such as glucose, galactose and fructose by the activation of different types of carbohydrate splitting enzymes that is amylases, maltase, lactase and sucrase.

Fate of Monosaccharide sugar after absorption : The monosaccharide sugars such as glucose, galactose and fructose are absorbed entirely into the capillaries of the villi and reach into the liver via portal vein. Small amounts of sugars may also be absorbed by the lymph. The galactose and fructose when reach into the liver, then and there they are apparently converted to glucose there. All the sugars are now converted into glycogen by the process of *glycogenesis*. Then the formed glycogen converts into glucose by the process of *glycogenolysis.* There is an additional process of glucose or glycogen formation taking place in the liver during emergency from non-carbohydrate precursors such as protein and fat by the process of *glyconeogenesis.*

Fate of Muscle Glycogen : The glucose which is formed from glycogen in the liver by the process of glycogenolysis, enters into the circulating blood and forms blood glucose. The range of blood glucose is 80 to 120 mg. per 100 ml of blood. This blood glucose enters into the muscle and forms muscle glycogen. According to *G. T. Cori* in 1931, the muscle glycogen produces Lactic acid after a sequence of reaction done by anærobic oxidation. The one-fifth part of lactic acid produces carbon dioxide and water through Kreb's Tri-carboxylic acid cycle but the rest four-fifth part enters into blood and forms blood lactate. This blood lactate enters into the liver and forms liver glycogen again.

Utilisation of Hexose sugar : The utilisation of glucose by the body consists of a series of bio-chemical changes which follow a well established pathway known as "EMP pathway" and finally an another distinct cycle of changes which constitute the "TCA cycle" of Krebs. For the proper conception of the entire catabolism, it is essential to note that glucose must be enzymatically degraded first to pyruvic acid stage and then this end product will be utilised for further degradation through the TCA cycle into CO_2 and H_2O. In fact, oxidation of carbon takes place in TCA cycle. Thus the EMP Pathway is the precursor and the TCA cycle is the follower and behave like a relay race during utilisation of glucose.

Most of our information about details of carbohydrate metabolism in animal tissues has been derived from the study of extracts of skeletal muscles. The whole process of oxidation of glycogen to carbon dioxide and water can be considered as occuring in two phases such as anærobic and ærobic.

I. Embden-Meyerhof-Parnas (EMP) pathway of breakdown of glucose : The process of glycolysis in tissues cansists in the breakdown of glycogen, glucose or other sugar to pyruvic and lactic acid. Although glycolysis was originally restricted to glycogen breakdown in muscle but it is now fairly generally applied to the aerobic breakdown of carbohydrate with the production of pyruvate and the liberation of energy. There are very many researches have to wide acceptance of the most mod-

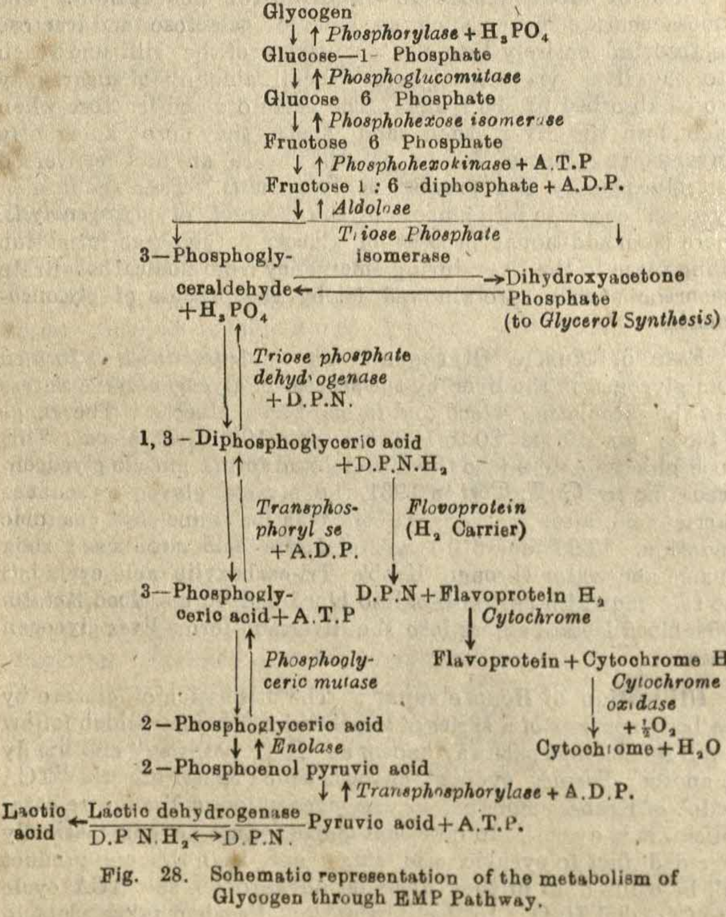

Glycogen
Phosphorylase + H₃PO₄
Glucose—1- Phosphate
Phosphoglucomutase
Glucose 6 Phosphate
Phosphohexose isomerase
Fructose 6 Phosphate
Phosphohexokinase + A.T.P
Fructose 1 : 6 diphosphate + A.D.P.
Aldolase
Triose Phosphate isomerase
3—Phosphoglyceraldehyde + H₃PO₄
Dihydroxyacetone Phosphate (to Glycerol Synthesis)
Triose phosphate dehydrogenase + D.P.N.
1, 3 – Diphosphoglyceric acid
+D.P.N.H₂
Transphosphorylase + A.D.P.
Flovoprotein (H₂ Carrier)
3—Phosphoglyceric acid + A.T.P
D.P.N + Flavoprotein H₂
Cytochrome
Phosphoglyceric mutase
Flavoprotein + Cytochrome H₂
Cytochrome oxidase
+ ½O₂
2—Phosphoglyceric acid
Cytochrome + H₂O
Enolase
2—Phosphoenol pyruvic acid
Transphosphorylase + A.D.P.
Lactic acid
Lactic dehydrogenase
D.P.N.H₂ ⟷ D.P.N.
Pyruvic acid + A.T.P.

Fig. 28. Schematic representation of the metabolism of Glycogen through EMP Pathway.

ern theory now known as "*Embden-Meyerhof-Parnas* (EMP)" pathway which offers a credible explanation by which glycogen molecules are converted to lactic acid. The glycolytic process of EMP pathway involves a series of reactions which may be briefly summarised as in Fig. 28.

II. **Tri-Carboxylic Acid (TCA) Cycle**: The oxidative degration of pyruvic acid molecule takes place in several steps to CO_2 and H_2O after passing through a series of changes converting its successively into 6—5—4 carbon acids. This cyclic series is known as "*Krebs citric acid cycle*" or '*glycolytic tri-carboxylic acid cycle*" after the discovery of an English biochemist, H. A. *Krebs* who first fomulated and proposed the mechanism in 1943.

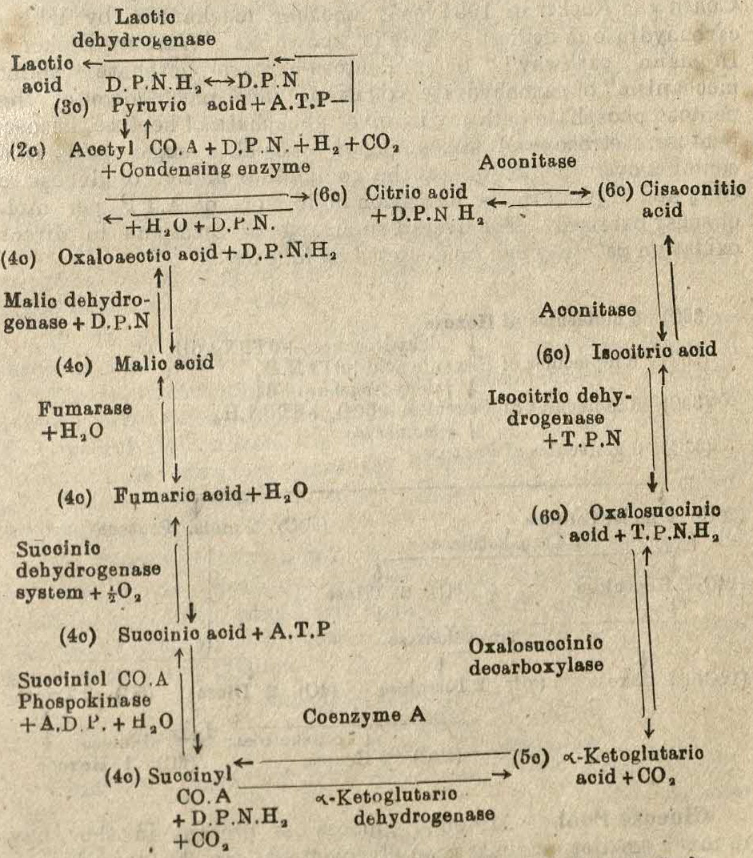
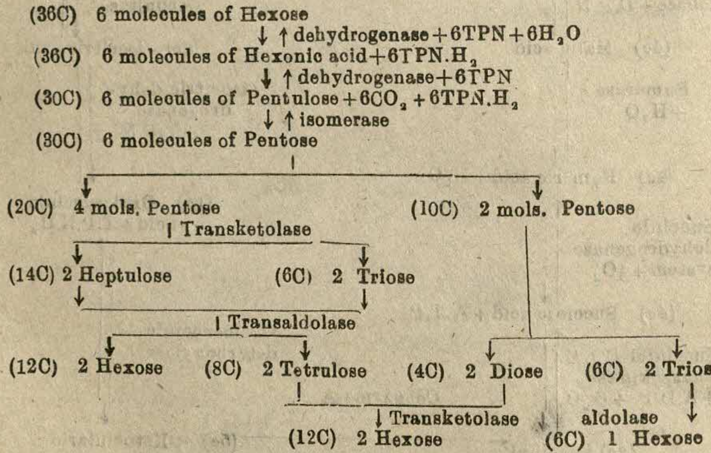

Lactic dehydrogenase
Lactic acid
D.P.N.H₂ ↔ D.P.N
(3c) Pyruvic acid + A.T.P
(2c) Acetyl CO.A + D.P.N. + H₂ + CO₂
+ Condensing enzyme
+ H₂O + D.P.N.
(6c) Citric acid + D.P.N H₂
Aconitase
(6c) Cisaconitic acid
Aconitase
(6c) Isocitric acid
Isocitric dehydrogenase + T.P.N
(6c) Oxalosuccinic acid + T.P.N.H₂
Oxalosuccinic decarboxylase
(5c) α-Ketoglutaric acid + CO₂
α-Ketoglutaric dehydrogenase
Coenzyme A
(4c) Succinyl CO.A + D.P.N.H₂ + CO₂
Succiniol CO.A Phospokinase + A.D.P. + H₂O
(4c) Succinic acid + A.T.P
Succinic dehydrogenase system + ½O₂
(4c) Fumaric acid + H₂O
Fumarase + H₂O
(4c) Malic acid
Malic dehydrogenase + D.P.N
(4c) Oxaloacetic acid + D.P.N.H₂

Fig. 29. Schematic representation of Tri-Carboxylic Acid Cycle with respective enzymes.

In is probable that the greater part of pyruvic acid oxidised first undergoes oxidative de-carboxylation to acetic acid which is then oxidised to CO_2 and H_2O through the tri-carboxylic acid cycle. The cyclic series of glycolytic TCA pathway is summarised as in Fig. 29.

Direct oxidation pathway of breakdrown of Hexose : In some tissues like retina, it is found out by *Warburg*. *Dickens*, *Lipmann* and *Dische* and specially worked out by *Horecker*, *Cohen* and *Racker* in 1954 that another mechanism by which carbohydrate is utilised. This is known as "Warburg-Dickens-Lipmann pathway" or "Pentose-heptose-phosphate shunt mechanism" of carbohydrate oxidation. The mechanism of the pentose phosphate pathway involves phosphate of heptose, hexose, pentose, tetrose and triose sugars and of a sugar acids in a complex cycle which effects the complete oxidation of glucose to CO_2 and H_2O with the formation of 36 mols. of A.T.P per mol. of sugar oxidised. The overall summary of reactions in direct oxidation pathway can be depicted as follows :



Glucose Pool : Although glucose is present in the body in much smaller amounts than glycogen, it can be regarded as the active fraction of the carbohydrate, while the glycogen represents the storage form. Glucose pool is an ideal concept of carbohydrate metabolism, from which glucose is constantly being withdrawn and which it is constantly being added. The glucose pool can be taken to be the glucose in the blood, together with that in the extracellular fluid in equilibrium with the blood The concentration of glucose in the blood will depend on a balance of the factors responsible for the adding glucose to the pool or removing it from the pool.

Q. 10. Describe the Intermediary Metabolism of Carbohydrate.

The amounts of galactose and fructose absorbed are normally small and these sugars are apparently converted to glucose, as soon as they reach the liver. No end product other than carbon dioxide and water is excreted during carbohydrate metabolism. Now glucose is not the only reducing substance in blood, the other reducing substances e.g. glutathione, remain fairly constant.

Different Intermediary Metabolic Processes : There are different types of intermediary metabolic processes of carbohydrate which are discussed as follows :

I. **Glycogenseis** (*Glycogen Formation*) **:** It is a process for the formation of glycogen from glucose that takes place both in the liver and in the muscle.

(A) **In the Liver :** (a) *Sources of Liver Glycogen :* (1) The hexose monosaccharide end products of carbohydrate digestion i.e. glucose, fructose, galactose. etc. (2) "Intermediates" of carbohydrate breakdown, especially lactic acid and pyruvic acid. (3) Glycerol derived from the hydrolysis of neutral fat. (4) Any "intermediate" derived from the breakeown of the amino-acids after deamination which enter into the so-called "metabolic pool".

(b) *Process of formation :* A number of substances may be synthesised to glycogen, among them galactose, fructose, mannose, glycerose, dihydroxy acetone, metlyl glyoxal, pyruvic acid, lactic acid, glycerol and several amino-acids e.g. alanine, glutamic acid and glycine.

$$\text{Glucose} + H_3PO_4 \xrightarrow{\text{Phospharylase}} \text{Glucose}-1-PO_4$$

$$\text{Glucose}-1-PO_4 + H_3PO_4 \xrightarrow{\text{Phosphoglucomutase}} \text{Glucose 1:6 diphosphate.}$$

$$\text{Glucose 1:6 diphosphate} \xrightarrow{\text{Phosphatase}} \textit{Glycogen} + H_3PO_4$$

(B) **In the Muscle :** The formation of Glycogen in the muscle takes place from glucose, fructose, mannose and galactose by the following ways :

Glucose$\rightarrow$Glucose $-6-PO_4\rightarrow$Glucose$-1-PO_4\rightarrow$*Glycygen.*

Fructose$\rightarrow$Fructose$-1-PO_4\rightarrow$Fructose$-6-PO_4\rightarrow$Glucose-$6-PO_4\rightarrow$Glucose$-1-PO_4\rightarrow$*Glycogen*.

Mannose→Mannose—6—PO_4→Fructose—6—PO_4→Glucose —6—PO_4→Glucose—1—PO_4→*Glycogen.*

Galactose→Glactose--1--PO_4→Glucose—1—PO_4→*Glycogen.*

II. **Glycogenolysis** (*Glucose Formation*) : It is a process for the liberation of glucose from glycogen in the liver and in the muscle. In the liver, the product of glycogenolysis is glucose which passes out into the blood as blood sugar. In the muscle, glycogen breaks down to pyruvic acid and lactic acid and this process is usually referred to as glycolysis.

(A) **In the Liver** : In the liver, glycogen is broken down not by direct hydrolysis but by an analogous process called phosphorolysis. Under the influence of *phosphorylase* enzyme and its co-enzyme *adenylic acid*, the long glycogen chain is broken down into glucose—1—PO_4 and by the activation of *phosphoglucomutase* and *glucose—6—phosphatase* enzymes, it will again broken down into glucose. The process of glycogen breakdown is as follows :

$$\textbf{Glycogen}+H_3PO_4 \xrightarrow{\text{Phosphorylase}} \text{Glucose—1—Phosphate}$$

$$\text{Glucose—1—}PO_4+H_3PO_4 \xrightarrow{\text{Phosphoglucomutase}} \text{Glucose—6-Phosphate}$$

$$\text{Glucose—6—}PO_4 \xrightarrow{\text{Glucose—6—Phosphatase}} \text{Glucose}+H_3PO_4$$

(B) **In the Muscle** : Fructose and galactose are converted into glucose in the muscle. Fructose is influenced by Fructokinase enzyme and Galactose is influenced by galactokinase enzyme. The stages of breakdown of fructose and galactose into glucose are as follows :

Fructose→Fructose—1—PO_4→Fructose—6—PO_4→Glucose —6—PO_4→*Glucose.*

Galactose→Glactose—1—PO_4→Glucose—1—PO_4→Glucose —6—PO_4→*Glucose.*

The conversion of galactose to glucose involves the nucleotide uridine-diphosphate-glucose (U. D. G.) as a co-factor.

III. **Glyconeogenesis** (New formation of glucose and glycogen from non-carbohydrate source) : It is a process by means of which liver glycogen can be built up from non-carbohydrate precursors like proteins and fat which are converted first into glucose and then into glycogen. The process of formation is as follows :

(a) **From Protein** ; (1) Ceriain anti-ketogenic amino-acids (i.e. glycine, alanine, cysteine, asparatic acid, ornithine, proline and hydroxyproline) after deamination yield keto-acids which can be built up liver glycogen. (2) During starvation, tissue protein is actually broken down and its anti-ketogenic amino-acids used for conversion to liver glycogen to maintain the blood sugar level.

(b) **From Fat** : The problem of the conversion of fat to carbohydrate has given rise to much controversial argument over many years and is not yet finally settled. Glucose may be formed from fat in very small amounts by the following processes: (1) Glycerol composing about 1/10 th of the fat molecule forms glucose. (2) Possibility of a fatty acids (especially with odd number of carbon atoms) conversion to carbohydrate is disputed but can not be dismissed. (3) Many of the organic acids involved in the citric acid cycle e.g. succinic, fumaric, citric, malic, oxaloacetic acids.

Q. 11. Describe the Citric Acid Cycle or Tri-Carboxylic Acid Cycle. What is Pasteur effect ?

The citric acid cycle formulated by *Krebs* in 1943 can be regarded as the final common pathway for the metabolism of proteins, fats and carbohydrates. The fats and carbohydrates both give rise to acetyl co-enzyme A. The glucogenic amino-acids form pyruvate and hence take the carbohydrate route and the ketogenic amino-acids form aceto-acetate and take the fat route. The cycle is an oxidative one and can only be kept going if a constant supply of D.P.N. is available in the oxidised form to act as a hydrogen acceptor for the various dehydrogenases involved. In the present account the following aspects of the citric acid cycle are discussed : (1) The reactions involved and the enzymes responsible for these. (2) The fate of the by-products produced, H_2 and CO_2. (3) The energy relations.

I. Reactions involved in Citric Acid Cycle :

(a) **Formation of Citric acid** : The cycle can be considered to start with the entry of aceyl co-enzyme A. This combines with oxalo-acetic acid to form citric acid, the catalyst being the condensing enzyme.

(b) **Formation of Cis-aconitic and Iso-citric acids** : The enzyme *aconitase* acts on citric acid to form first cis-aconitic acid and then iso-citric acid.

(c) **Formation of α-Ketoglutaric acid** : Iso-citric acid is converted to α-Ketoglutaric acid, oxalo-succinic acid being an intermediate stage. The reaction involves T.P.N. as a hydrogen acceptor and the overall process omitting the intermediate stage of oxalo-succinic acid.

(d) **Formation of Succinic acid :** The oxidative decarboxylation of ∝ ketoglutaric acid to form succinic acid is a complex process involving conezyme A, lipoic acid and possibly several enzymes. D.P.N. acts as a hydrogen acceptor. Succinyl coenzyme A is formed as an intermediate and during the process, one molecule of A.T.P. is formed from A.D.P.

(e) **Formation of Fumaric Acid :** Succinic dehydrogenase removes 2H atoms from Succinic acid to form fumaric acid. Succinic dehydrogenase which is a flavoprotein, does not require D.P.N. as a co-enzyme and the cytochrome system can act directly as H-acceptor. Succinic dehydrogenase can be competitively inhibited by malonic acid as it was found that in tissues poisoned with malonate, pyruvate was quantitatively converted to succinate.

(f) **Formation of Mailc Acid :** Fumarase acts on fumaric acid to form malic acid.

(g) **Formation of Oxalo-acetic Acid :** Malic acid is dehydrogenated by malic dehydrogenase to form oxalo-acetic acid. In this process, D.P.N.$^+$ acts as hydrogen acceptor. The oxaloacetic acid now reacts with another molecule of acetyl co-enzyme A and the cycle is complete.

II. **Evidence's of Citric Acid Cycle :** The critic acid cycle represents the chief mechanism for the oxidative production of energy in all the body tissues.

(1) *Szent-Gyorgyi* and *Stare* and *Baumann* found that the four-carbon dicarboxylic acids, succinic, fumaric, malic and oxaloacetic, powerfully increase catalitically the oxygen uptake and carbon dioxide production by muscle and other tissues. The oxidation of succinic to fumaric acid is inhibited by malonate and the conversion of fumaric to malic acid is blocked by arsenite.

(2) *Martins* showed that citric, iso-citric and cis-aconitic acids are readily interconvertible in tissues and *Martins* and *Knoop* found that citric acid is converted to ∝-ketoglutaric acid.

(3) *Krebs* and *Johnson* demonostrated that muscle tissue rapidly oxidizes ∝-ketoglutaric acid to succinic acid. The oxidation appears to involve three stages as follows : (i) Combination of the enzyme ∝-ketoglutaric acid oxidase, in the presence of Mg^{++} and thiamine pyrophosphate (T.P.P) to form a complex which decomposes to yield CO$_2$ and so-called active succinic semialdehyde. (ii) Oxidation of the active succinic semialdehyde to succinyl COA. (ii) Hydrolysis of succinyl COA by a deacylase enzyme.

(4) Oxaloacetic acid is highly reactive in tissues and plays a key role in the citric acid cycle. It is the catalytic molecule

which brings the acetyl COA of fatty acid oxidation and of carbohydrate and amino-acid metabolism into the cycle for oxidation.

III. Relation of Enzymes with Citric Acid Cycle :

(1) The enzymes of citric acid cycle are associated in cytoplasmic particles (liver mitochondria, muscle sarcosomes) with the enzymes of the respiratory chain of electron transfer from reduced pyridine nucleotides and flavins to oxygen.

(2) The close association of the citric acid cycle with this multi-enzyme system provides a means for the continuous reduction of electron carriers thus transferring energy from pyruvate to oxidation-reduction systems.

(3) The inhibitor of citric acid cycle is fluoroacetate which is biological systems that gives rise to the formation of fluorocitrate. This product is formed by the enzyme-catalysed condensation of fluoro-acetyl COA and oxalo-acetate and inhibits competitively the action of aconitase.

IV. Fate of the Products of Reactions of Citric Acid Cycle : The products of reactions are : (1) The CO_2 formed is one of the end product of citric acid cycle. It diffuses into the blood and is excreted through the lungs. (2) This four pairs of hydrogen atoms are dealt with for transfer of metabolic hydrogen to molecular oxygen. In three of the four cases, the intermediate hydrogen acceptor is D.P.N. or T. P. N., which passes the hydrogen on to the cytochrome system. (3) In the case of succinic dehydrogenase, the D.P.N. stage is omitted. The pairs of hydrogen-atoms are finally passed to the cytochrome oxidase which is able to use molecular oxygen as a hydrogen acceptor, the molecular oxygen being supplied by the respiratory system. (4) At the decarboxylation of α-ketoglutarate, H_3PO_4 and A.D.P. enter while A.T.P. leaves which means a balance of entry of water while another water enters at the formation of malate. At two stages, CO_2 leaves and at four stages, a pair of hydrogen atoms.

V. Energy Relations of Citric Acid Cycle : The energy of metabolism can only be used for biological work when it is stored in the form of A.T.P. and this is achieved by coupling with some exergonic reaction and the endergonic reaction. A.D.P. $+ H_3PO_4 \rightarrow$ A.T.P. $+ H_2O$. It is in fact that most of the reactions coupled with A.T.P. production are those in the electron—and H-transferring systems. The oxidation of each D.P.N.H. or T.P.N.H. yields three molecules of A.T.P. and the flavoprotein system connected with succinic dehydrogenase yields two. In addition, one molecule of A.T.P. is generated in the formation of Succinate from α-ketoglutarate. The electron transferring system shows that for each molecule of pyruvate oxidised by the citric acid cycle, 15 molecules of A.T.P. are generated.

Pasteur Effect ; The operation of the aerobic mechanisms of carbohydrate breakdown inhibits the rate of conversion of glucose to pyruvic acid. This inhibition, by oxygen, of the rate of carbohydrate breakdown is frequently called the "*Pasteur effect*". In 1861, Pasteur found, in his studies on alcoholic fermentation, that under anaerobic conditions much more sugar was taken up, per quantity of yeast present, than was consumed in the presence of air. This effect, later termed by Warburg the "*Pasteur reation*", has been observed with many types of cells from a variety of organisms, including animals and plants.

Q. 12. Describe the Alternate Pathways of Carbohydrate metabolism.

There are a number of alternate pathways regarding carbohydrate metabolism which are the following :

I. Embden-Meyerhof Glycolytic Pathway : The process of glycolysis in tissues consists in the breakdown of glycogen, glucose or other sugars to pyruvic acid and lactic acids. The glycolytic process is necessary for most phases of carbohydrate metabolism except the interconversion of glycogen and sugars. It is obligatory to one pathway of carbohydrate oxidation, since the pyruvic acid formed by glycolysis is then oxidised to CO_2 and water in the tricarboxylic acid cycle. This oxidation is the source of most of the utilizable energy (A.T.P.) derived from carbohydrate metabolism. The sequence of chemical changes preliminary to and directly concerned in glycolysis is indicated below :

Add Embden-Meyerhof Cycle of Q. 9 (*Page No* 158)

II. Hexose-Monophosphate Oxidation Shunt (Pentose pathway or Pentose cycle or Phosphogluconate oxidative pathway or Warburg-Dickens-Lipmann pathway) :

Add Direct Oxidation Pathway of Breakdown of Hexose of Q. 9 (*Page No. 160*)

Overall Summary of Reactions :

$6\ \text{Hexose}-PO_4 + 3O_2 \rightarrow 6O_2 + 6\ \text{Pentose}-PO_4$

$4\ \text{Pentose}-PO_4 \rightarrow 2\ \text{Hexose}-PO_4 + 6\ \text{Pentose}-PO_4$

$2\ \text{Pentose}-PO_4 + 2\ \text{Tetrose}-PO_4 \rightarrow 2\text{Hexose}-PO_4 + 2\ \text{Triose}-PO_4$

$2\ \text{Triose}-PO_4 \rightarrow \text{Hexose}-PO_4 + \text{Inorganic phosphate.}$

Summary $\text{Hexose-}PO_4 + 3O_2 \rightarrow 6O_2 + \text{Inorganic phosphate.}$ 6 mols. of water would be formed in the process and 36 A.T.P. per mol. of hexose oxidised.

III. **Glucuronic Acid Cycle** (Glucuronate Pathway) : This cycle involves the formation of glucuronic acid from glucose —6—phosphate, the formation of xylulose from the glucuronic acid, conversion of xylulose to xylulose—5—phosphate and finally, formation of glucose—6—phosphate from xylulose—5—phosphate by the pentose phosphate cycle. So, glucuronic acid cycle is a combination of a number of cycles.

IV. **Entner-Doudoroff Pathway** : *N. Entner* and *M. Doudoroff* in 1952 have showed the conversion of 6-phosphogluconate to 2-keto-3-deoxy-6-phospho-gluconate by an enzyme system. This reaction which is of major importance in "pseudomonas fluorescens" requires the presence of $Fe^{2+}$and glutathione or cysteine. The hexose chain is then cleaved to form pyrurate and glyceraldehyde-3-phosphate by aldolase-like reaction.

V. **Glyoxylate Cycle** : Glyoxylate is formed from iso-citric acid. *Kornberg and Krebs* in 1957 formulate a glyoxylate cycle which may be summaried as follows : Glyoxylate→Malate→Acetate→Oxalo-acetate→Citrate + Acetate→ Cis-Aconitate→Iso-citrate + Succinate→Glyoxylate. The glyoxylate cycle has common intermediates with the citric acid cycle.

Q. 13. How Fat is metabolised in the body ? What is Lipid pool ?

The metabolism of any substance is the fate of that substance after it has been absorbed into the blood. The metabolism of fat is nothing bnt the the fate of digestive end products of fat such as fatty acids and glycerol after they have been absorbed into the blood.

Fatty food stuffs taken as a form of diet : The fatty food stuffs which are generally taken in daily day life as a form of diet are the fats and oils, glycolipide, chromo-lipide, amino-lipide, saturated and unsatuated fatty acids, tocopherols, etc.

Digestion : The fat converts into one molecule of glycerol and three molecules of fatty acids by the activation of different types of fat splitting enzymes such as gastric lipase, pancreatic lipase, intestinal lipase, tissue lipase, etc. The end products of fat digestion are : (1) Mainly 70% unhydrolysed, water insoluble, neutral fat which under normal conditions in the intestine has been reduced to a finely emulsified state. (2) Water-soluble and diffusible fatty acid-bile salt complex. (3) Mono-glycerides and di-glycerides, some soluble and some emulsified forms. (4) Glycerol which is water-soluble and diffusible.

Absorption : The digestive end products of fat are absorbed mainly through lacteal channel and partly through intestinal epithelium. A number of theories have been presented by different scientists like *Munk*, *Verzar*, *Frazer* and *Pfluger* regarding fat absorption but none of which has enjoyed universal acceptance.

Circulation : The fat after absorption reach into the blood in the following forms : (1) Mainly as neutral fat and fatty acids. (2) As lecithin and other choline-containing phospholipides. (3) As free cholesterol and cholesterol esters.

Storage : The fat after circulation, stores in different places of the body like : (1) In the sub-cutaneous connective tissue as a form of *sub-cutaneous fat.* (2) In the fold of mesentry of the abdominal cavity as a form of *mesentric fat.* (3) In intermuscular connective tissue as a form of *neutral fat.* (4) In greater and lesser omentum as a form of *omental fat.*

Mobilisation : The lipolytic enzymes which are concerned in the process of mobilisation from storage form of fat into circulation form, are as follows : (1) Gastric lipase. (2) Pancreatic lipase. (3) Intestinal lipase. (4) Tissue lipase. The process of mobilisation of fat by tissue lipase becomes : (i) It converts the tissue fat into storage form of fat. (ii) It converts the storage form of fat into circulating form of fat. (5) Blood lipase.

Utilisation of Fat : The oxidation of fat probably involves, first, the hydrolysis of the molecules into glycerol and fatty acid and then the oxidation of the two components.

(A) **Oxidation of Glycerol :** The oxidation of glycerol takes place in the following ways : (1) Glycerol, like glucose, gives rise to glycogen in the liver, though it is true, not the same extent. (2) In diabetes produced by means of phlorhzin, glycerol is practically quantitatively converted to glucose.

The glycerol converts into glycogen by chemical reactions with the activation of different types of enzymes and the process of breakdown of glycerol is as follows : *Glycerol*→2-phosphoglyceric acid→3-phosphoglyceric acid→1 : 3-diphosphoglyceric acid→1 : 3-diphosphoglyceraldehyde→3-phosphoglyceroaldehyde→Phospho-dihydroxy acetone→Fructose 1 : 6-diphosphate → Fructose-6-Phosphate→Glucose-6-Phosphate →Glucose-1-phosphate→*Glycogen*.

Oxidation of Fatty Acid : The end products of fatty acid oxidation are the acetone bodies which are produced in the liver. These acetone bodies are β-hydroxybutyric acid, aceto-acetic acid and acetone. The first two products undoubtedly partial oxidation product of butyric acid and the acetone may be regarded as derived form of aceto-acetic acid by the loss of carbon dioxide. The inter convertability of aceto-acetic acid and β-hydroxy butyric acid can be accomplished by the use of a suitable dehydrogenase and co enzyme. There are a number of theories come forward regarding oxidation of fatty acid but none of them come into final conclusion.

I. **Knoop's β-oxidation Theory :** It is the first theory of fatty acid oxidation. **History :** The first contribution about the fatty acid oxidation was made by *Knoop* in 1905. **Materials Required :** In the fatty acid oxidation, palmitic acid is taken that contains 16 carbon atoms. **Conditions for Oxidation :** (1) The process of oxidation takes place at first in β-position. (2) Then subsequent hydrolysis takes place. **Results :** The palmitic acid after oxidation forms 8 molecules of acetic-acid. **Cancellation :** From Knoop's β-Oxidation theory, we get 8 mols. of acetic acid, but from the oxygen consumption study, it has been seen that we get one mol. of keto-acid and six mols. of acetic acid. So, Knoop's β-oxidation theory has been rejected.

II. **Hurtley's Alternate Multiple Oxidation Theory :** It is another theory of fatty acid oxidation. **History :** This theory was establishd by *Hurtley* in 1915. **Materials Required :** Palmitic acid is taken for oxidation which contains 16 carbon atoms. **Conditions for Oxidation :** (1) All β-positions of palmitic acid are first oxidised to carbon monoxide. (2) Then hydrolysis takes place subsequently. **Results :** From the Alternate β-oxidation theory, we get 6 mols. of acetic acid and one mol. of aceto-acetic acid. **Cancellation :** We know from further observation that formation of four mols of Aceto-acetic acid takes place during fatty acid oxidation but Multiple β-oxidation theory is not able to show the formation of those aceto-acetic acids. So, Multiple β-Oxidation theory has been rejected.

III. **Mackay's Acetic-Acid Condensation Theory :** It is another theory of fatty acid oxidation. **History :** This theory was established by *E. M Mackay* in 1940. **Materials Required :** Palmitic acid is taken for oxidation which contains 16 carbon atoms. **Conditions for Oxidation :** (1) The oxidation takes place at the β-position and simultaneously at every alternate higher carbon atom and oxidised into carbon monoxide (2) Then subsequent hydrolysis takes place. **Results :** The oxidised palmitic acid is converted into 8 mols. of acetic acid. Each pair of acetic acid molecule condenses to form one molecule of aceto-acetic acid. Therefore palmitic acid after oxidation forms 4 mols. of aceto-acetic acid which are subsequently oxidised to CO_2 and water, Palmitic Acid $+ 7O_2 \rightarrow$ 8 mols. of Acetic acid.

8 mols. of Acetic Acid $\rightarrow$ 4 mols. of Aceto-acetic acid $+ 4H_2O$.

4 mols. of Aceto-acetic acid $+ 16O_2 \rightarrow 16CO_2 + 12H_2O$.

Cancellation : We know from further observation that formation of dicarboxylic acid takes place during the fatty acid oxidation but Acetic-acid condensation theory is not able to show the formation of dicarboxylic acid during this process. So, Acetic-acid condensation theory has been rejected.

IV. **Omega-Oxidation Theory** : It is the newer theory of fatty acid oxidation which merely acts in a supplementary manner. **History** : *Verkade Flaschentrager* and others have established this theory in 1938. **Materials Required** : Palmitic acid is taken for oxidation which contains 16 carbon atoms. **Conditions for Oxidation** : (1) The terminal methyl group (omega position) may be first oxidised to carboxyl group. (2 β-oxidation proceeds from both ends and converts into carbon monoxide. (3) Then the subsequent hydrolysis takes place. **Results** : From Omega oxidation theory of palmitic acid, we get 6 mols. of Acetic acid and one molecule of Di-carboxylic acid.

Discussion : We know from different types of oxidation of fatty acids that acetic acid, dicarboxylic acid and aceto-acetic acid are formed. So any one of these theories has not been able to satisfy the formation of three things at a time. But Knoop's β-oxidation theory is much more appreciated and more credit should give to Knoop because all the theories take the help of β-oxidation theory and other theories are also not to be neglected because they make the way of perfection of β-Oxidation Theory.

Lipid Pool : To maintain the lipid pool in equilibrium position, lipids bring constantly withdrawn from pool or added to it. The lipid outside the lipid pool consist of two main functions—those that form part of structure of the cells or part of the cell secretions and those that represent storage or depot lipids. (a) *Lipids are added to the pool* : (1) By absorption from the intestine. (2) By synthesis in various sites. (3) By mobilisation from the fat depots. (b) *Lipids are removed to the pool* : (1) Storage in the fat deposits. (2) Utilisation by tissues for structural fats (3) Use by glands, e.g. production of milk fats by mammary glands or production of steroid hormones by various endrocrine glands. (4) Oxidation by the liver. (5) Excretion in bile.

Q. 14 How Fatty Acid is oxidised in the body ?

Fat after digestion forms fatty acids and glycerol after the activation of different types of fat splitting enzymes. The glycerol portion of fat molecule gives rise to glycogen in the liver. The fatty acid after oxidation, forms acetone bodies in the liver. The acetone bodies are acetone, acetic acid and β-hydroxy butyric acid. The acetone may be regarded as derived form of the aceto-acetic acid by the loss of carbon dioxide molecule and the rest two acetone bodies are undoubtedly partial oxidation product of butyric acid.

Oxidation of Fatty acid : The molecule of an unsaturated fatty acid such as oleic, is not likely to undergo oxidative attack at the point of unsaturation but the saturated acid such as stearic, palmitic are degraded by terminal oxidation. Several theories have been proposed to explain the mechanism of the oxidation of fatty acids but none of them come into final conclusion.

I. **Knoop's β-oxidation Theory** : The classical theory of **Knoop** in 1905 held that fatty acids are oxidised in successive stages in each of which the point of oxidative attack is the carbon atom in the β-position, so that as the result two "C" atoms are "etched away" at a time and forms acetic acid.

Evidences : (1) β-oxidation of fatty acids has been demonostrated in the vitro by oxidising their ammonium salts with H_2O_2 at 37°C (2) Various fatty acids were perfused with isolated livers or incubated with fresh liver slices and evidence of β-oxidation was found. (3) In diabetes and starvation, aceto-acetic acid and β-hydroxy butyric acids are formed. These acids are β-oxidation products of butyric acid.

Conclusion drawn by Knoop : (1) During oxidation of two carbon atoms due to oxidation at the β-carbon atoms. (2) Acetic acid was split off each stage of the process, though neither he nor others was able to isolate the acid. (3) The final products must be either Benzoic acid or Phenyl acetic acid and such acid by combination with glycerine will be eliminated as Hippuric acid and Phenyl aceturic acid respectively.

Views against Knoop's Concept : According to *Embden* in 1906, the prefusion of liver with even numbered straight chain fatty acids led to the appearance of aceto-acetic acid after dehydrogenation and its de-carboxylation product is the acetone or ketone bodies. These are found in appreciable amount in the blood and urine of diabetic animals and diabetic human subjects. It was also reported by *Embden* that the perfusion of liver with odd-numbered straight chain fatty acids did not lead to the appearance of ketone bodies.

II. Hurtley's Alternate Multiple Oxidation Theory.

This theory was first established by *Hurtley* in 1915. According to this theory the higher chain of fatty acids are oxidised into aceto-acetic acid. The oxygen combines with the carbon atoms situated at the β-position and simultaneously also at alternate carbon atoms there by the higher fatty acids into aceto-acetic acids.

Views Supporting Hurtley's Idea :

(a) **Embden's View :** He could not show the aceto-acetic acid that is formed from odd number of fatty acids.

(b) **Quastel and Jowett's View :** According to *J. H Quastel* and *M Jowett* in 1935 that oxidation can proceed simultaneously at alternate carbon atoms along the fatty acid chain. The oxidation products would break up into molecules of aceto-acetic acid and acetic-acids.

(c) **Mackay's View :** According to *E. M. Mackay* in 1940 that the oxidation of fatty acids takes place at the β-position and simultaneously at every alternate higher carbon atoms. The fatty acids after oxidation converts into an even number of acetic acid molecule and two of the acetic acid molecule condenses to form a single molecule of aceto acetic acid.

(d) **Weinhouse's View :** *S. Weinhouse* is 1944 performed experiments in which isotopic octanoic acid was incubated with the liver slices and aceto-acetic acid has isolated from the incubation mixture and analysed for C^{13}.

(e) **Gurin and Crandall's View :** *S. Gurin* and *D. I. Crandall* in 1948 showed that the ratio of C^{13} in the CO and COOH groups was less than unity and it has been interpreted to indicate a non-random association of the C_2 units formed by the oxidation of carboxyl-labelled fatty acids.

III. **Omega-oxidation Theory :** This theory was established in 1938. According to this theory, with some fatty acids certain amount of dicarboxylic acid are excreted in the urine. The terminal methyl group (Omega position) may be first oxidised to the carboxylic group and then β-oxidation proceeds from both sides. *P. E. Verkade*, *Flaschentrager* and others have succeeded in isolating dicarboxylic acid from urine after feeding short chain fatty acid to their animals.

IV. **View of Lynen :** *Lynen* and others in 1951 have forwarded their idea of fatty acid oxidation where co-enzyme A participates in the reaction They observed that both the synthesis and breakdown of fatty acid involves a two carbon compound ,which are removed or added to. It is very likely that acetic acid in an active form has the possibility of being that two carbon compound and *Lipmann* in 1950 has shown that it is the acetyl COA. In the oxidation of fatty acid, a chemical reaction takes place between the fatty acid, ATP and thiol ester of coenzyme A. There are five stages of reactions in fatty acid oxidation which are *activation stage*, *dehydrogenation*, *hydration*, *dehydrogenation* and *thiolytic cleavage* successively. The reactions are as follows : (1) **Activation** : Fatty acid is activated by *thiokinase* in presence of coenzyme A, ATP and Mg^{++} and coenzyme A ester or activated fatty acid is formed. (2) **Dehydrogenation** : The activated fatty acid is oxidised by *acyl* ~ *COA dehydrogenase* by the removal of two hydrogen atoms and α-β-unsaturated activated fatty acid is produced. (3) **Hydration** : The α-β-unsaturated fatty acid undergoes hydration with the addition of water by the activation of *enoyl hydrase* or *crotonase*, β-hydroxy activated fatty acid is formed. (4) **Dehydrogenation** : The β-hydroxy activated fatty acid is catalysed by *β hydroxyacyl COA dehydrogenase* with the removal of two hydrogen atoms, forms β-keto activated fatty acid. (5) **Thiolytic cleavage** : β-Keto activated fatty acid is cleavaged at β-carbon atom by the activation of *thiolase* in presence of COASH, fatty acid is completely splitted into two-carbon fragments. So, palmitic acid that contains 16-carbon atoms is broken down into eight fragments of acetyl COA. The process of breakdown of fatty acid oxidation is as follows :

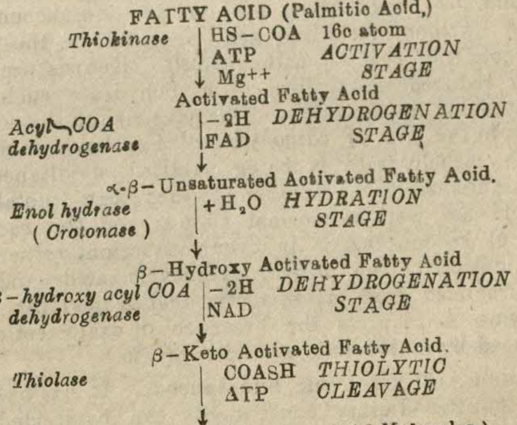


Fig. 30. Schematic Representation of Fatty Acid Oxidation with respective enzymes and Activators.

Energy Production in Fatty Acid Oxidation : The first stage of β-oxidation of fatty acid forms two mols of A.T.P per two H atoms oxidised, while the second stage of oxidation forms three A.T.P. Thus for each cleavage of a fatty acid, five A.T.P are produced. The oxidation of a molecule of Acetyl COA in the citric acid cycle forms 12 A.T.P. The palmitic acid contains 16 carbon atoms and β-oxidation takes place seven times, with the formation of $7 \times 5 = 35$ A.T.P. Eight molecules of Acetyl COA are formed, which when oxidised in the citric acid cycle yield $8 \times 12 = 96$ A.T.P. Thus, the total A.T.P. formed in the complete oxidation of a mol. of palmitic acid is $35 + 96 = 131$ mols. One molecule of A.T.P. is required to "spark" β-oxidation per mol. of fatty acid through formation of Acetyl COA and 130 mols. net of A.T.P. are produced. Each mol of A.T.P. represents about 7000 Cal. for free energy stored for metabolic use, so the oxidation of a mol of palmitic acid yields about $130 \times 7000 = 910{,}000$ Cal. of utilizable energy.

The combustion of palmitic acid to CO_2 and H_2O liberates a total of 2,330,500 Cal. per molecule. Consequently, the quantity of this total energy converted into the utilizable energy of A.T.P. is $910{,}000/2{,}330{,}00 \times 100 = 39\%$.

Q. 15. What is Ketosis? Describe the origin and formation of ketone bodies. What is the effect of ketosis? Discuss its interrelation with carbohydrate, blood, urine and endocrine glands.

In certain conditions, products of fatty acid metabolism, aceto-acetic acid, β-hydroxybutyric acid and acetone, accumulate in the blood (*ketonaemia*) and are excreted in the urine (*ketonuria*), a condition that is called *ketosis*. Ketosis occurs in a condition of reduced metabolism of carbohydrate such as in diabetes mellitus and in starvation. This gave rise to the concept that "*fats burn in the fire of carbohydrate*" i.e. they can only be oxidised when carbohydrate is being oxidised simultaneously. It is now established that diabetic tissues can metabolise acetoacetic acid as well as normal tissues and the cause of accumulation of ketone bodies is over production, rather than diminished oxidation. The β-hydroxy-butyric acid and the acetone are produced from aceto-acetic acid in the liver. The Acetyl Co-enzyme A requires the presence of oxalo-acetic acid which is produced by metabolism of carbohydrate.

Ketogenic and Anti-ketogenic Substances : It has been for a long time that the dietary constituents can be divided into ketogenic and anti-ketogenic substances. The anti-ketogenic substances include carbohydrate and most of the amino-acids, while the ketogenic substances include fats and a few amino-acids. If the ketogenic substances being oxidised amount to less than twice the anti-ketogenic, the ketosis does not result.

ites of Origin of the Ketone Bodies : (1) It is generally accepted that the liver is by for the most important site of production of ketone bodies. The perfused liver produces abundant quantities of ketones while little comes from kidneys, lung and skeletal muscle. (2) *Himwich* and his associates found that liver consistently added ketones while striated muscle, heart and the organs drained by the portal vein only occasionally added small amounts of ketones and sometimes removed them from the blood. (3) *Jowett* and *Quastel* found that slices of spleen, testis, brain and kidney produced small amounts of ketone bodies but liver slices formed 10 to 40 times more.

Mode of Formation of Ketone Bodies : The term "*Ketone bodies*" applied to the ketone acid, aceto-acetic acid and acetone and β-hydroxybutyric acid which are derived from aceto-acetic acid :

(1) Aceto-acetic acid → Acetone.

(2) $\text{Aceto-acetic acid} \underset{\text{Dehydrogenase}}{\rightleftarrows} \text{L-}\beta\text{-Hydroxybutyric acid.}$

Free aceto-acetic acid is formed from aceto-acetyl COA largely in the liver which is rich in deacylase enzyme. The over-all process is :

$$CH_3-CO-CH_2-CO-S-COA+HOH\xrightarrow{\text{Deacylase}}HS-COA+CH_3-CO-CH_2-COOH$$

Effects of Ketosis (Utilisation of Ketone Bodies) : (1) Ketone bodies in small or moderate amounts provide a source of energy for tissues when the supply of carbohydrate is restricted or its utilisation is impaired (2) Aceto-acetic and β-hydroxybutyric acids formed in liver cells are non-volatile and moderately strong acids which must be neutralised by base as soon as they enter the blood stream. (3) In severe ketosis, i e. when the rate of formation greatly exceeds that of utilisation there may be a dangerous disturbance in acid-base equilibrium. Thus ketosis results in a loss of base, water, nitrogen and energy and leads to acidosis and dehydration. (4) It has been shown that even the tissues of the diabetic animals can oxidise completely the ketone bodies even if no sugar is burning.

Inter-relation with Carbohydrate Metabolism : Ketones only appear when enough sugar is not burnt. Ketones can be utilised freely without any help of sugar oxidation. The inter-relation between sugar oxidation and ketone formation lies in the fact that in diabetes and starvation, the glycogen content of the liver becomes low. Since in these two conditions, no sugar is burning the energy repuirement of the body must be supplied from the oxidation of fats.

Relation of ketosis with Blood and Urine reaction : During ketosis, aceto-acetic acid, β-hydroxy-butyric acid etc. are formed.

Since, these are all acids, ketosis is usually associated with a condition of acidosis in the body and increased acidity of the urine. Due to this relation between acidosis and ketosis, acetone bodies are generally found in highly acid urine. But it must be remembered that acidosis is the result and not the cause of ketosis.

Role of Endocrines on Ketosis :

(1) *Ketogenic hormone of Anterior Pituitary* : This hormone produces severe ketosis in diabetes and starvation. The seat of action of this hormone is liver. If liver is removed this hormone fails to produce ketosis. The ketogenic hormone mobilises depot fat, increases the fat content of liver, stimulates oxidation of more fats in this organ, so that more ketones are formed.

(2) *Insulin* : It prevents ketosis and its administration clears up the ketosis of diabetes. This effects is due to the following : (i) It increases liver glycogen, prevents mobilisation of fats from the depots and thus reduces liver fats. (ii) Consequenty fat oxidation is discouraged and more carbohydrates burn. These lead to less ketone formation, so that ketosis clears up.

(3) *Thyroxine and Adrenaline* : These increase ketosis under certain conditions. Their actions are probably due to decrease of liver glycogen and its consequent loading with fat.

(4) *Hormones of the Adrenal Cortex* : Extracts of adrenal cortex are also ketogenic. The mode of action of adrenal cortical hormone are ketone bodies is not well known uptil now.

Q. 16. What is Fatty Liver ? Describe the cause and formation of fatty livers.

Under a variety of conditions neutral fat or cholesterol esters may accumulate in the liver to a very much greater extent than in other tissues. Mammalian liver normally contains about 5% of lipids, but under the influence of various pathologic and physiologic disturbances the lipid content may rise to 25% to 30%. These fatty livers are much larger and paler than normal livers, the greater part of the increase in weight of the liver is due to accumulation of glycerides and water phospholipids and free cholesterol remain remarkably constant, cholesterol esters increase significantly whenever glycerides increase.

Causes of Fatty Livers .

(a) **Causes of Fatty livers due to Deficiencies** : (1) *Essential fatty acids*—Interfere with phospholipid synthesis. (2) *Choline*—Interferes with phopholipid synthesis. (3) *Pyridoxine*—Increases demand for inositol and choline. (4) *Pantothenic acid*—Effect is unknown. (5) *Thyroid hormone*—Lowers metabolism.

(b) **Causes of Fatty livers due to Excess :** (1) *Cystine*—Stimulates appetite and metabolism. It diverts methionine. (2) *Cholesterol*—It competes for fatty acids and essential in phospholipid synthesis. (3) *Guanido-acetic acid*—It takes up methyl groups to form creatine. It interferes with choline synthesis. (4) *Thiamin*—It increases appetite and metabolism. It diverts methionine from choline synthesis. (5) *Biotin*—It increases demand for inositol. (6) *Riboflavin*—It increases appetite and metabolism (7) *Niacin*—It causes choline deficiency by taking choline methyl groups. (8) *Anterior pituitary hormone*—It effects possibly due to fat-mobilising factors known as adipokinin (9) *Adernal cortical hormone*—It increases mobilisation of fat to liver (10) *Female sex hormones*—The mechanism of action is uncertain.

(c) **Cause of Fatty livers due to position :** Phosphorous, choroform, etc. cause tissue injury and lowered capacity to metabolise lipids that brought to liver.

Conditions resulting Fatty Livers : Some conditions which result in an excessive deposition of fat in the liver are as follows : (1) *Starvation* : The fatty liver of starvation is clearly seen in some species of animals. It disappears when the fat reserves are exhausted. (2) *Anterior Pituitary Extract Injection* : The injection in fasting animals of a fraction obtained from the anterior pituitary gland cause fatty livers (3) *Insufficiency of Insulin* : The insulin insufficiency cause fatty livers. (4) *Dietary deficiency* : The diets deficient in choline or its precursors, diets rich in fat or containing excessive amounts of cholesterol, dificient in protein. (5) *Enviornmental changes* : The reduced atmospheric pressure e.g. at high altitudes or elevated temperatures. (6) *Poisons* : Phosphorous, chloroform and other chlorinated compounds, benzol, ketone, phoridzin or bacterial toxins. (7) *Clinical conditions* : Kwashiorkor, a world wide malignant undernutrition, diabetes mellitus, pernicious anaemia, yellow fever, pregnancy cause fatty livers.

Formation of Fatty Livers :

(1) *Fatty livers in diabetic animals not receiving Insulin* : Fatty livers in diabetic animals, maintained without insulin, mobilise large amounts of depot fat into the blood stream to supply their energy requirements. This fat, with that of the diet, is transport to the liver for the initial stages of metabolism. When the animals are given insulin, enabling them to oxidise carbohydrate, the lipids of plasma and liver decrease.

(2) *Fatty livers due to dietary deficiencies or alternations* : It has been found that fatty livers result from various dietary deficiencies and alterations They may be produce by carbohydrate deprivation and by a deficiency of unsaturated essential fatty acids, of choline, of methionine and of the vitamins

pyridoxine and pantothenic acid. Fatty livers may also result from the ingestion of excess cholesterol, cystine, serine, guanidoacetic acid and of the vitamins thiamine, biotin and niacin.

(3) *Fatty livers due to carbohydrate deprivation* : When rats or mice are given diets containing much fat and free from carbohydrate, the livers accumulate large amounts of fat. The fatty livers due to starvation and high fat, low carbohydrate diets, like those of diabetic animals, without insulin, may be considered physiologic fatty livers.

(4) *Fatty livers due to deficiency of unsaturated fatty acids* : Tha body is capable of synthesizing the more unsaturated fatty acids such as linoleic, linolenic and arachidonic and they are referred to as the essential fatty acids leads to accumulation of excess fat in the liver and presumably this is due to incapacity of the liver to synthesise phospholipids with consequent inability property to metabolize fat, which accumulates.

(5) *Fatty Livers due to choline deficiency* ; A choline deficiency leads to fatty livers, because choline is required for phospholipid synthesis in the liver and this is necessary in the processes of fat metabolism in the liver. Any process which slows down the rate of phospholipid synthesis and turn over in the liver that leads to cause fatty livers,

(6) *Fatty livers due to cholesterol feeding* : *Best* and *Ridont* have shown that the feeding of cholesterol to rats produces fatty livers which contain an exaggerated proportion of cholesterol as well as excess netural fat.

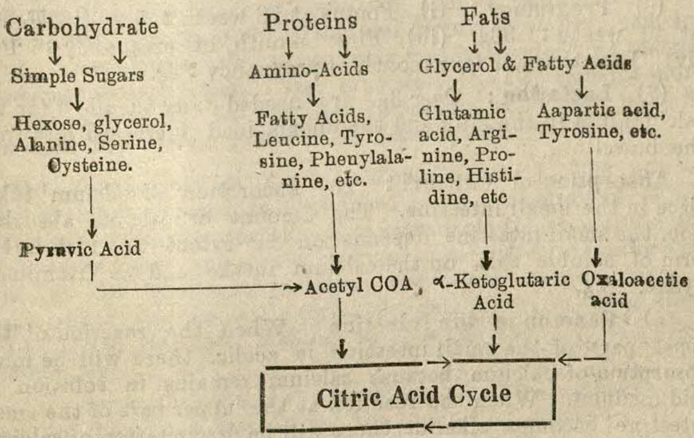
Q. 17. Discuss the integration of Carbohydrate, Fat and Protein metabolism through the Tri-carboxylic Acid Cycle.

According to *Kreb*, the first major stage of energy transformation in living matter terminates in the synthesis of A.T.P. at the expense of the free energy liberated during metabolism. A few basic processes that are concerned in energy transformations are Oxidation, Reduction, Dehydration, Decarboxylation Acetylation, Phosphorylation, Amination and Transamination. For carbohydrate, protein and fat metabolism, the three key substances that are formed prior to any significant energy liberation are : Acetyl CO A, α-ketoglutaric acid and Oxaloacetic acid. These are broken down in the citric acid cycle to liberate over two-thirds of the cellular energy.

Certain of the amino-acids like leucine, tyrosine and phenylalanine are deaminated and oxidise to form aceto-acetic acid which is oxidised through tricarboxylic acid cycle. Acetyl COA fromed from these amino-acids may also be used for the synthesis of fatty acids may also be cholesterol and for acetylations. Other amino-acids like alanine, cystine, cysteine and serine form pyruvic acid which may be oxidised through tri-carboxylic acid cycle or be converted to glucose and glycogen by reverse glycolysis or converted to Acetyl COA and utilized for the synthesis of fatty acids and cholesterol and in the acetylation process.

Aspartic and glutamic acids dircetly enter the tri-carboxylic acid cycle at the oxaloacetate and α-Ketoglutarate stages from which their oxidations done. These substances may lead to increased production of pyruvate with sugar and glycogen formation and also through pyruvate to Acetyl COA which can yield fatty acids and cholesterol that can be utilised for acetylations. The same statements are true for arginine, histidine, ornithine and proline which enter through tri-carboxylic acid cycle indirectly through glutamic acid at the α-ketoglutarate stage.

Summary of Metabolism of Fats, Carbohydrates and Proteins :


Carbohydrate
Simple Sugars
Hexose, glycerol, Alanine, Serine, Cysteine.
Pyruvic Acid
Proteins
Amino-Acids
Fatty Acids, Leucine, Tyrosine, Phenylalanine, etc.
Fats
Glycerol & Fatty Acids
Glutamic acid, Arginine, Proline, Histidine, etc
Aapartic acid, Tyrosine, etc.
Acetyl COA,
α-Ketoglutaric Acid
Oxaloacetic acid
Citric Acid Cycle

Q. 18. Describe the Calcium Metabolism.

Calcium, invariably present in all animals and essential for growth, is a constituent of all biological tissue and fluids and is a valuable mineral with an important role in physilogical processes

Sources of Calcium : Calcium is present mainly in milk, cheese, green vegetables but other good sources are eggs, meat, butter, orange, nuts, carrots, fish and flour, (a) *Milk* : The milk contains 120 mg. of calcium per 100 ml. but human milk contains 30 mg. per 100 ml. (b) *Meat* : It contains very little calcium and is about 10 mg. per 100 gm. (c) *Green Vegetables* : Most green vegetables contain calcium but the amount of calcium is very less. (d) *Flour* : It contains 20 to 25 mg. of calcium per 100 gm.

Forms of Occurence : The different froms of calcium are found generally as : (a) Insoluble salt such as tricalcium phosphate, calcium carbonate, calcium fluoride etc. (b) Blood calcium.

Daily Requirements : The normal daily requirement of calcium in different periods of human beings are the following :

(1) **Adult :** 12 mg. per kg. or 750 mg. in all.

(2) **First six months :**

(i) Breast fed : 45 mg. per kg.

(ii) Artificially fed (cow's milk) : 150 mg. per kg.

(3) **From six month to nine years :** 800 to 900 mg.

(4) **From nine to sixteen years :** 1000 to 2000 mg.

(5) **Over sixteen years :** Gardually decreasing to adult level i. e. 700 mg.

(6) **Pregnancy :** (i) Foetus at 28 weeks : 5g. (ii) Foetus at 40 weeks : 30g. (iii) First month of pregnancy : 1·5g. (iv) Last three or four month of pregnancy : 3g.

(7) **Lactation :** Over 3g. are needed daily to allow for the calcium loss in the milk and the unexplained increased loss from the bowel.

Absorption of Calcium : The absorption of calcium takes place in the small intestine. The amount of calcium absorbed from the small intestine depends on the extent to which in the form of soluble salt, on the calcium intake and on Vitamin D intake.

(a) **Reacton in the Intestine :** When the reaction of the upper part of the small intestine is acidic, there will be more absorption of calcium because calcium remains in solution in acid medium. When the reaction at the upper part of the small intestine becomes alkaline, there will be precipitation of calcium phosphate and calcium carbonate which are insoluble and will be excreted out along with the faeces.

(b) **Steatorrhoea :** In this condition, a large amount of fat is excreted out with the faeces and much of the food calcium is precipitated as insoluble and unabsorbable calcium-soap of fatty acids.

(c) **Phytic acid :** It is a constituent of flour which precipitates the calcium in the intestine as insoluble and unabsorbable calcium phytate This insolube calcium phytate is excereted out along with faeces.

(d) **Vitamin D :** It helps in the absorption of calcium from the intestine. In presence of Vitamin D, the reaction of the intestine is acidic which keeps the calcium in solution so that calcium may be easily absobed from the small intestine,

Calcium in Blood : The calcium in the blood is almost entirely in the plasma, determinations are usually made on serum. The normal level of blood calcium is 9 to 11·5 mg. per 100 ml. Calcium in the blood exist in two forms such as non-diffusible and diffusible froms. The total amount of diffusible blood calcium is 5 to 6·5 mg. per 100 ml. This diffusible calcium may be present in the blood as ionised and non-ionised forms. The *ionised calcium* is 4·75 to 6·25 mg. per 100 ml. of blood and *non-ionised calcium* is 0·25 mg. per 100 ml. of blood,

Regulation of Blood :

(a) *Serum Calcium Level depends on* : The calcium level of blood depends on the following : (1) The amount of calcium absorbed from the small intestine. (2) The *parathyroid hormone* maintains the normal calcium level by helping inthe reabsorption of calcium from the kidney tubules. If parathormone level in the blood is diminished, there will be more excretion of calcium with the urine and blood calcium level will be diminished. (3) The *plasma inorganic phosphate level* regulates serum calcium level. The plasma calcium generally varies inversely as plasma phosphate concentration. The product of the two remains more or less constant. If, therefore, inorganic phosphate level is increased, the calcium level will be decreased and vice-versa.

(b) *Serum Calcium Level is diminished in* : The normal calcium level of blood is diminished in the following : (1) When there is diminished absorption of calcium from the small intestine such as in ricket and steatorrhoea or when calcium intake very low. (2) In hypoparathyroidism, the serum calcium level is diminished. (3) In some forms of renal failure in which there is phosphate retention leading to a secondary fall of serum calcium level

(c) *Serum Calcium Level is raised in* : The normal calcium level of blood is raised in the following cases : (1) In Hyperparthyroidism. (2) In higher concentration of plasma protein. (3) After administration of very large doses of Vit. D. (100,000 to 500,000 units per day), (4) After sudden immobilization. e. g. confinement to bed with extensive plaster casts as after fracture of the spine.

Excretion of Calcium : The excretion of calcium is done chiefly in the faeces and slightly through urine. Calcium is excreted out with the urine of about 25% to 35%. The amount excreted out may vary from 50 to 250 mg. per day.

Functions of Calcium : Dietary calcium is absorbed into the blood stream as soluble calcium and after absorption it serves with an important role in the following physiological processes.

(1) **Formation of bone and teeth :** Calcium helps in the formation of bone and teeth. For the formation of bone, the

product of calcium and phosphorus must be constant and it becomes less than normal, there will be defective formation of bone.

(2) **Caogulation of blood :** Calcium takes very important part in the coagulation of blood. Calcium ion is essential for the conversion of inactive prothrombin into active thrombin with the help of blood or tissue thromboplastin. This active thrombin then converts the soluble fibrinogen of the plasma into insoluble fibrin which forms the clot. If calcium ion in the blood gets precipitated by the addition of sodium or potassium oxalate or citrate solutions, coagulation is retarded.

(3) **Curdling and production of milk :** Calcium ion is essential for clotting of milk protein cæsinogen. The insoluble cæsinogen is converted into soluble cæsin by the milk curdling enzyme known as rennin. This soluble cæsin combines with calcium ion to form insoluble calciumcæsinate. Calcium is utilised in milk production by the lactating breast One quarter of human milk contains about 400 mgms. of calcium.

(4) **Neuro-muscular excitability :** The regulation of neuro-muscular excitability depends upon the balance between calcium and magnesium ions and the sodium and potassium ions. However calcium acts as neuro-muscular sedative.

(5) **Cardiac Rhythmicity :** The maintance of rhythmicity of cardiac muscle contraction appear to depend upon the proportions of calcium, magnesium, sodium and potassium ions in the muscle fibre.

(6) **Membrane permeability :** Calcium has the fundamental role in the regulation of membrane permeability. The capillary permeability can be markedly increased by perfusing with solution low in calcium ion.

(7) **Activation of certain enzymes** · Calcium ion is essential for the activation of certain enzymes and thereby it acts as an activator of lipase, succinic dehydrogenase and adenosine-tri-phosphatase.

Q. 19. Describe the Metabolism of Iron.

Iron is one of the inorganic trace element helps in the dispensable and indispensable nature in animal and in plant nutrition. It functions in the body as an essentaial part of many oxidation-reduction enzyme and is contained in several other biologically significant proteins.

Sources : The main sources of iron are present in the body and food.

I. **Body Iron :** The body of an adult man contains about 4·5 gms. of iron which is distributed of blood haemoglobin, myohaemoglobin, intra-cellular enzymes, ferritin compound etc.

II. Iron in the Food : The animal food contains iron in minute amounts which vary with the ferritin and blood content. The approximate iron content of the different food stuffs are Meat (3·5 mg./gm%), Liver (7 mg./gm%). Egg (2·5 mg/gm%). Bread (1 mg/gm%). Cabbage (1 mg./gm%). Rice and Potato (0·5 mg/gm%) and Milk (very small amount).

Daily Requirement : The requirement of iron depend upon the storage of iron in the body. If iron is stored in sufficient amount, the daily iron requirement is minimum The daily need of iron varies according to the age and stage of theindividual. (1) *In children* : They need 0·6 mg. of iron per kg. of body weight per day. (2) *In adult* : The daily need of iron for adult are about 12 mg. (3) *In pregnant and lactating females* : They need a daily diet including 20 mg. of iron.

Absorption of Iron : A part of the iron of our food stuffs is converted into iron salts by the gastric hydrochloric acid and then it is reduced by the various food reducing agents known as glutathione, ascorbic acid etc.

The absorption of iron takes place largely in the small intestine and as ferrous ions. Ferritin is present in the intestinal mucosal wall which is composed of a protein called apoferritin and ferric hydroxide The iron in the ferritin is not bound chemically but is loosely present. Iron in the ferrous form enters the mucosal cells and is stored in ferritin as ferric hydroxide when the blood serum iron level decreases, ferritin iron is converted to ferrous ions which enter the blood stream when the content of iron ferritin decreases to some critical point. more iron from the intestine is absorbed into the mucosal cells.

When the apoferritin is fully saturated with iron in the mucosal cells, food iron is not absorbed from the small intestine and will be excreted out with fæces. When the blood iron level is diminished, ferritin in the mucosal cells will be converted into apoferritin. and ferrous ions which will go to the blood. The iron concentration in the muscosal cells will be diminished and more iron will be absorbed from the small intestine.

Blood Iron : Iron is present in the blood in two forms :

(a) **As haemoglobin :** In the red blood cells 15 gms. of haemoglobin per 100 ml. of blood corresponds to 50 mg. of inorganic iron.

(b) **As plasma iron** : Iron is present in the plasma in combination with the β-globulin forming side rophilin or transferrin and plasma iron is present in the ferric form. The plasma iron amounts to 0·05 mg per 100 ml.

Storage of Iron : The liver, spleen and bone marrow are the principal iron storage depots in the body. Ferritin and an iron protein complex which has been obtained from the liver, spleen and bone marrow, when radio-active iron is injected, it is stored in the liver as this ferritin.

Excretion of Iron : The body iron is never excreted with the faeces but it is excreted with urine. The food iron which is not absorbed from the small intestine will be excreted out with the faeces. A trace of iron excreted from the liver as bile pigments along with bile.

Functions of Iron : Iron has got many fold functions :

(1) **Synthesis of Haemoglobin :** The most important function is to help in the synthesis of haemoglobin. Iron will conjugate with the porphyrin compound to give rise to haem, This combination is catalysed by copper, cobalt, nickel and managaneese.

(2) **Supply and storage of oxygen to the muscles :** Iron present in the myohaemoglobin in the muscle that will take oxygen from the blood and this oxygen is stored in the muscle by conjugating with myohaemoglobin.

(3) **Related to tissue oxidation process :** The different enzyme system in the body such as cytochrome, peroxidase, catalase that contain iron and this iron may combine with the oxygen to help in the process of oxidation of different food stuffs.

(4) **Cell Nucleus formation :** The chromatin granules in the nuclei are made up of iron and therefore iron takes part in the formation of chromatin granules.

(5) **Regulation of peripheral circulation :** A hepatic vaso-depressor principle (VDM) involved in the regulation of peripheral circulation was concentrated from beef, dog and human liver.

(6) **Related with oxidation process of nerve cell :** Nissl granules contain organically combined iron and is present in the cytoplasm of the nerve cells. This iron plays an essential role in the process of oxidation in the nerve cells.

Q. 20. What is Basal Metabolic Rate ? What are the different factors that modify Basal metabolic rate ? Describe a method for the determination of Basal metabolic rate.

The basal metabolic rate is the energy output of an individual under standardized resting condition, i.e at complete bodily and psychical rest under comfortable conditions of temperature, pressure and humidity, 15 to 18 hours after a meal (Post-absorptive period) In adult male, it is about 40 calories per sq. metre of body surface per hour and in adult female it is about 37 calories.

Factors modifying Basal Metabolic Rate :

I. **Physical Factors : (a) Suface Area :** The basal metabolism is most closely related to the surface area and is less directly related to height the weights. According to *Du Bois*, the surface area can be calculated if the height and weight are known. $A = {}^{0\cdot425} \times H^{0\cdot725} \times 71\cdot84$ where, A = Surface area in sq cm. W = Weight in kg and H = Height in cm (b) **Age** : The basal metabolism is considerably greater per sq. metre of surface in children than in adults. There is a further gradual fall in the metabolism during adult life as age advances. (c) **Intake of food :** The taking of food stimulates the process of metabolism. This effect is not equally marked with all claases of food stuffs, being least with the carbohydrate and fat and greatest with protein. (d) **Muscular work :** During muscular work, basal metabolic rate is increased due to the increased tissue metabolism. (e) **Starvation or prolonged undernutrition** : During starvation, B.M.R. is greatly diminished. Similarly in prolonged undernutrition, B.M R. is also diminished.

II. **Hormonal Factors : (a) Thyroid Gland :** The hormone thyroxine of the thyroid gland will directly stimulate the tissue metabolism and as a result B.M.R. is increased.

(b **Supra-renal medulla** : The hormone adrenaline of the supra-renal medulla directly stimulates the tissue metabolism and as a result B.M.R. is increased. (c) **Anterior Pituitary gland** : The metabolic hormone of the antertor pituitary gland will increase the B. M R. by stimulating the tissue metabolism.

III. **Enviornmental Factors : (a) Body Temperature :** For every rise of 1°F in the internal temperature of the body the basal metabolism increases by 7%. (b) **External Temperature** : Exposure to cold increases the tissue metabolism and thereby heat production will be increased. Exposure to external heat will stimtlate the parasympathetic system which will inhibit the sympathetic system and as a result there will be less secretion of thyroxine and adrenaline and therefore tissue metabolism will greatly diminished. (c) **Barometric Pressure :** Moderate reduction of atmospheric pressure does not affect the B.M.R., but a fall of pressure to half an atmosphere, as occurs in mounitain climbing, reduces B.M.R.

IV. **Sexological Factors** : (a) **Pregnancy :** After six month of pregnancy, B.M.R. of the mother rises. The basal metabolic rate of the pregnant woman is the sometotal of her own metabolism in the non-pregnant state and that of the foetus. So, pregnancy has got no specific effect upon B.M.R. (b **Sex** : In males B.M.R is slightly higher than in females. So, in male, B.M R. is about 4) calories per sq. metre of body surface per hour and in adult female it is about 36 calories,

V. **Psychological Factors : (a) Emotional Excitement** : During emotional excitement, there will be over activity of the sympathetic system which will cause increased secretion of thyroxine and adrenaline. These two hormones will stimulate the tissue metabolism and thereby there will be rise of B.M.R. **(b) During Fear and Anger** : During fear, B.M.R. is decreased but during anger, there will be secretion of adrenaline causing rise of B.M.R.

VI. **Clinical Factors** : (a) *In Lymphatic leukaemia*, B.M.R. is increased for no very clear reason. (b) In *Pernicious anaemia*, a less marked increase of B.M.R. in found and also in *heart disease* when decompensation i.e. failure to maintain an adequate circulation is present. (c) In *Exophthalmic goitre*, a thyroxine secretion is increased and the basal metabolism may increase in severe case upto double the normal and thereby the B M.R is raised upto +100. (d) *In Myxoedema* in which there is less secretion of thyroxine and the metabolic activity may be depressed to 60% or 70% of the normal and thereby the B M.R. is—30 or—40.

Methods of Determination of B.M.R. : B.M.R. can be determined by Direct and Indirect Calorimetry.

I. **Direct Calorimetry** : It can be done with the help of a specially heat proof chamber known as *Atwater-Benedict's respiration calorimeter*. It can be hardly used in clinical purpose.

II. **Indirect Calorimetry** : This can be done by the following **ways** :

(A) By determining the Surface Area : The suface area of the subject is determined and it multiplied by the calorific eqivalent per square metre of body surface per hour. Surface area can be determined by noting the height and weight of the individual and then with the help of *Du Bois formula* :

$$A = W^{0.425} \times H^{0.725} \times 71.84 \text{ (constant)}$$

where, A=Surface area in sq. cm. ; Weight in kg. ; H=Height in Cm.

(B) By determining the Pluse rate and Pluse pressure : By the determination of the pulse rate and pulse pressure, B.M.R. can be determined by the formula :

(1) *Read's Fromula* :

$$\therefore \text{ B M.R.} = 0.75\,(\text{P.R} + 0.74\text{ P.P}) - 72$$

where, P R = Basal Pulse Rate and P.P. = Basal Pulse Pressure.

(2) *Gale and Gale's Formula* : They introduced a simpler formula in 1931.

$$\therefore \text{ B.M.R.} = \text{P.R.} + \text{P.P} - 111$$

where, P.R. = Basal Pulse Rate and P.P. = Basal Pulse Pressure.

(C) By noting the Gaseous Exchange : B.M R. is caculated from the oxygen consumption alone. CO_2 output is not determined. The R. Q. becomes 0 75 because the subject is almost fasting. In man, the amount of oxygen consumption during a given period is determined indirectly by an instrument known as *Benedict-Roth Apparatus.*

Principle : The patient breaths oxygen which circulates through a closed chamber. The carbon dioxide formed is absorbed and oxygen consumed is measured at the end of the experiment.

(b) **Description of the Apparatus** : The apparatus consists of a spirometer chamber which is filled up with oxygen from the oxygen cylinder. There is one soda lime chamber which will dissolve carbon dioxide with the formation of sodium carbonate. There are two tubes, one for inhalation of oxygen and another for output of carbon dioxide. The tubes so adjusted by valvular arrangement that the gas will always flow in one direction. The apparatus is connected with a writing lever which will give the record on a moving smoked drum.

Before performing the experiment, the nose is clipped. The tubes are introduced into the mouth cavity through which the patient will respire. Before the experiment the spirometer chamber is filled up with oxygen and as the patient will consume oxygen there will be gradual fall of spirometer bell which will be recorded in the moving drum. The record is taken for 6 minutes. The decrease in the volume of oxygen in the chamber is a direct measure of oxygen consumption.

(c) **Calculation** : Suppose the fall of spirometer bell is (80 − 2) or 78 m.m.

For 1 m m. fall of the spirometer bell oxygen consumption = 20·73 ml.

Therefore, for 78m.m. fall oxygen consumption = 78 × 20·73 ml. = 1617 ml. in 6 minutes.

For consumption of 1000 ml. oxygen, heat production = 4·82 Cal.

Therefore, for consumption of 1617 ml of oxygen,

$$\text{Heat production} = \frac{4{\cdot}82 \times 1617}{1000}\text{Cal.} = 7{\cdot}79 \text{ Cals. in 6 mins.}$$

In 6 mins B.M.R. = 7·8 Calories

$$\therefore \quad 1 \text{ min. B.M.R.} = \frac{7{\cdot}8}{6}\text{Cal} = 1{\cdot}3 \text{ Calories.}$$

Q. 21. Describe the metabolism in Starvation.

There will be complete deprivation of water, salts and food in total starvation. The total starvation kills the subject in the shortest possible time. The deprivation of water kills the animal in about one week, that of salt in two weeks, where as food derives energy first from the combustion of its own carbohydrate stores like glycogen, next the fat reserves mainly are drawn upon and finally after these have been exhausted, tissue protein is broken down, the fatty acid part of the molecule is burned while the nitrogen is excreted in the urine mainly as urea.

Different Types of Disturbances during Starvation :

I. **GeneralConditions** : There is a craving for food particularly at meal times during the first two days. Water and salts when freely allowed, craving subsides. Gradually the desire for food vanishes, weakness increases and the individual has a strong dislike to undertake any physical and mental work. Then the subject falls into a state of semi-consciousness but pulse rate and the body temperatute remain almost normal. The period of sleep increases and rate of respiration become slow, temperature falls, amount of urine formation slower and the stool is formed and passed as it is.

II. **Loss of Body Weight** : During the first few days the sub-cutaneous tissues and other fat depots are burned, large quantities of extra-cellular water are lost and at last dissolution of protoplasmic structure occurs. The central nervous system loses only about 5% of its weight and the muscles loses about 35% or more during prolonged starvation. The weight losses of muscular tissue, liver, gastro-intestinal tract and spleen run approximetely parallel with that of the body as a whole. The muscle fibres are reduced in size and many are destroyed. The kidney loses only 20% or less of its weight and the gonads, adrenals and thyroid only loose 2% to 8%

III. **Rate of Metabolism :** The gradual diminution of body weight causing reduction in surface area and the total metabolism of body falls. The subject is abnormally sensitive to cold, due to fat that the skin vessels are constricted in an attempt to reduce the dissipation of it through radiation and convection. The specific dynamic respond to food may be increased,

IV **Nitrogen Excretion :** The total output of nitrogen in the urine falls for the first day or two of the fast when the body is maintaiuing upon its carbohydrate supply. It usually reaches a maximum about the third or fourth day but from then is shows a progressive decline and may reach a value of less than 6 gms. per day The ammonia excretion rises but the creatinine output falls. The average daily loss of body protein of an average sized man during starvation is about 50 gms or about 0·4% of the total amount in his body.

V. **Ketosis** : The increase in urinary ammonia is a result of the production of excessive amounts of β-hydroxy butyric acid and aceto-acetic acid. Fasting ketosis is much more pronounced in woman than in men. The lean woman excretes larger amount of ketone bodies than does a man of overweight.

VI **Carbohydrate Metabolism :** Carbohydrate store becomes almost utilized in the first two days. The blood sugar level falls and maintains at a low but steady level due to the process of glyconeogenesis in the liver. Glucose tolerance is reduced but glycosuria takes place producing a condition known as "*Starvation diabetes.*" In the earlier stages there may be temporary hypoglycaemia.

VII **Lipid Metabolism :** Due to the absence of carbohydrates for oxidation becomes incomplete, producing ketosis. The loss of internal fat which normally serves to support the organs like stomach, kidneys, uterus etc. against the effect of gravity results in there displacement producing "*Viceroptosis*".

VIII. **Mineral Metabolism :** The urinary excretion of phosphorus and sulphur shows an initial rise and then a gradual fall results. Towards the letter part of the fast the N : P and N : S ratios are around 5·3 : 1 and 14 : 1 respectively. The urinary excretion of cloride, sodium, potassium and magnesium is reduced from the begining of the fast.

IX. **Blood Changes :** There will be acidosis with diminished alkali reserve, low blood sugar, increased blood fats, presence of ketone bodies and raised potassium ions in case of fast.

X. **Urine Changes :** There will be less urine volume, fall of nitrogen, presence of creatine and ketones, increased ammonia excretion and rise of acidity and potassium level in case of starved individual.

XI. **Susceptibility to infections** : (1) It is natural to suppose that the production of γ-globulin which is so closely associated with immune bodies would depressed by undernutrition, specially if involving severe protein deficiency. (2) It is recognised that some non-infectious conditions such as hypertension, neoplatic diseases and diabetes are beneficial by undernutrition.

XII **Psychological Changes** : Mental apathy, moral detoriation, depression, tendency toward introversion and other changes in personality and lowered intellectual capacity are common effects during prolonged starvation of an individual.

Q. 22. Describe the Metabolism of Sulphur.

Sulphur is one of the inorganic trace element, help in the regulation of elasticity in various tissues of the body, oxygen carriage, milk clotting, blood clotting and detoxication.

Source : The various forms of source of sulphur are the following :

(a) **Organic Sources :** (1) *Sulphur-containing amino-acid*, viz, cystine, cysteine, methionine, etc. (2) *Sulphur containing proteins*, viz, mucin as mucoitin-sulphuric acid cartilage proteins as chondroitin-sulphuric acid, etc. (3) *Sulpholipids or Sulphatids* present in the nervous tissue. (4) *Thiamin*, a member of the Vitamin B complex. There is no metabolism of the substances belonging to organic group because they are excreted through urine.

(b) **Inorganic Sources :** (1) *Compounds containing sulphates* viz, sodium sulphate, potassium sulphate and Magnesium sulphate, etc. (2) *Salts ef sulphate*, these are present in common vegetables.

Digestion : (1) *Tyrosine* or *Phenyl alanine* undergo bacterial putrifaction in the intestine and it is convertetd into phenol and cresol. (2) *Tryptophan* undergoes bacterial putrifaction and is converted into indole and skatole.

Absorption : (1) The *phenol and cresol* which are the breakdown product of Tyrosine, are absorbed by the blood vessels and carried to the liver where they are conjugated with sulphuric acid and form one group of ethereal sulphates. (2) The *Indole* and *Skatole* which are the digestive product of Tryptophan, are absorbed by the intestinal epithelium that are toxic in nature. They are detoxicated by the liver by at first oxidising them into indoxyl and skatoxyl. Then they are conjugated with sulphuric acid and potassium and form other group of ethereal sulphates.

Sulphur in Blood : The sulphur present in the blood as : (1) Sulphur circulates in the amount of 2.2 to 4.5 mgm. per 100 ml. of whole blood. (2) It is present as 1.7 to 3.5 mgm. per 100 ml. of serum.

Distributions of Sulphur : (1) Sulphur rich tissue are found as *Keratin* in the hard appendages of the body, i.e. hair, nail, hoof, horns, feathers, etc. (2) In the cartilage, (3) In nervous tissue as a form of sulpholipoids, (4) In various forms of glycoproteins like mucin. (5) In the red blood corpuscles as a constituent of haemoglobin. (6) Glutathione is present in traces in almost all cells. (7) Sulphur is present in the enzymes like rennin, lipase, phosphatase, etc (8) Insulin hormone is a sulphur compound. (9) Sulphur is present in heparin. (10) The body pigment melanin contains sulphur. (11) Bile salts like taurocholate and glycocholate particularly. (12) Urinary sulphur found in the urine as a form of Inorganic sulphates, Ethereal sulphates or Organic sulphates and Neutral sulphur.

Effect of Deficiency : (1) *Cystinuria* : It is the type of disease when cystine increases in the blood and is excreted in large amount through urine. (2) *Melanotic Sarcoma* : In this case, abnormal sulphur containing pigment is appeared in the urine.

Excretion of Sulphur : Sulphur is excreted in the following ways :

(a) **Through the Saliva :** Sulphur as a form of thiocyanates and traces of inorganic sulphates, is excreted through saliva. Thiocynates are specially found in the smoker's saliva which gives a deep brown colour with ferric chloride.

(b) **Thgough the Stool :** Sulphur is excreted through the stool as one of the element along mucin, sulphurated hydrogen (H_2S gas) and bile salts.

(c) **Through Urine :** Sulphur is excreted through urine by the following forms : (1) As *Inorganic Sulphates* : Sulphur as a form of inorganic sulphates formed from the exogenous protein metabolism, excreted through urine. (2) As *Ethereal Sulphates* : (i) Ethereal sulphates formed by the conjugation of absorbed phenol and cresol with sulphuric acid and excreted through urine. (ii) Ethereal sulphates formed by the conjugation of absorbed Indole and Skatole with sulphuric acid and potassium and excreted through urine. (iii) Indican is an example of ethereal sulphates and it is excreted through urine.

Functions of Sulphur :

(1) **Related to Hardness and Elasticity** : Sulphur is related to the maintenance of hardness with certain amount of elasticity in various tissues of the body like hairs, hoofs, horns, cartilages, nails, etc.

(2) **Constituent of Methionine** : It ia a constituent of methoinine that is an essential amino-acids.

(3) **Related to Bile Salt :** Taurocholic acid of bile is derived from taurine which is a sulphur-containing amino-acids.

(4) **Related to Respiration and Oxidative Process :** Sulphur is related to oxygen carriage and the oxidative processes of the body. (i) Glutathine is a sulphur containing tripeptide which takes part an important role in tissue oxidation. (ii) Haemoglobin contains sulphur. It carries oxygen in the blood. (iii) It is an ingredient of the diabetogenic hormone known as Insulin which is to stimulate the oxidation of sugar. (iv) It is a constituent of thiamine and biotin which fall under Vitamin B-complex that take part in tissue oxidation.

(5) **Relation with Milk Clotting :** Sulphur has got relation with milk clotting because milk coagulating enzyme "rennin" contains sulphur.

(6) **Related to Blood Coagulation :** Sulphur is related with blood coagulation. Heparin, an anti-coagulant contains sulphur.

(7) **Process of Detoxication** : Sulphur is used in the process of detoxication by the following ways : (i) Cystine, a sulphur containing amino-acid is used in the detoxication of poisonous substances such as bromobenzene that is excreted as mercapturic acid. (ii) The exogenous sulphur is oxidised into sulphuric acid which is partly used to detoxicate substances like indoxyl and forms ethereal sulphate.

Q. 23. Describe Water Metabolism.

Water is the most important and essential substance for life. A man can live without salt and food but he cannot live on earth without water

Source : Water constitutes more than 60% of the total body weight. It is present in the cellular and vascular spaces and small portions are also deposited in conjunction with protein and carbohydrate.

Chemistry : Water having formula H_2O with a molecular weight 18 and a polymer of H_2O. Its critical temperature becomes 365°C. An ordinary water is a mixture of boiling water, $(H_2O)_3$ and ice, $(H_2O)_4$.

Distribution : The percentage of water content in various tissues are as follows : Saliva, 99% ; Cerebro-spinal fluid, 99% ; Vitreous humour, 98·5% ; Embryonic brain 91% ; Milk, 88% ; Grey matter of the brain, 86% ; Kidney, 83% ; Thyroid, 77% to 82% ; Thymus, 81% ; Suprarenal gland, 80% ; Blood, 79% ; Pancreas, 78% ; Muscle, 73% to 78% ; Spleen 76% ; Liver, 70% ; Skin, 72% ; White matter of brain, 68% ; Tendon, 56% to 68% ; Cartilage, 67% ; Elastic tissue, 50%, Bone 50% (Vertebrae and ribs, 16% to 44% and Extremities and skull, 12% to 24%) ; Fat, 20% and Dentine, 10%.

Daily Requirement : The total daily requirement of water becomes 3,000 ml. The needs of the body for water are met in two ways : (a) *By direct intake* : 200 ml of water it derived from the water in foods and from the products of oxidation of foodstuffs in the body. (b) *By oxidation of foodstuffs in the body* : The amount of water liberated as a result of the oxidation of food stuffs is approximately 10 to 14 gm. per 100 Calories. For example, 100 gms. of fat when oxidised, produces 107 ml. of water and equivalent to 930 Cals. Carbohydrate and protein equivalent to 100 Cals each will produce 13·5 and 10·1 ml. of water respectively.

Regulation of water balance : The anti-diuretic hormone of the posterior lobe of the pituitary controls the gain and loss of water volume. *Du Bois* gives the following figures illustrating intake and output of water of a nephritic patient.

(a) Water Intake :

(1)	Drinking water ...	300 ml.
(2)	Water in coffee, milk and soup	580 ml.
(3)	Water in solid foods ...	720 ml.
(4)	Water from oxidation of 100 gms. of protein	41 ml.
(5)	Water from oxidation of 100 gms. of fat	118 ml.
(6)	Water from oxidation of 244 gms of carbohydrate	135 ml.
	TOTAL	1894 ml.

(b) Water Output :

(1)	In Urine	750 ml.
(2)	In Faeces	180 ml.
(2)	Vaporized through skin	550 ml.
(4)	Voporized through Lungs ...	350 ml.
	TOTAL	1830 ml.

Functions : Water has possessed a many fold physiological functions which are stated below :

(1) **Constituent of living Cell :** Water is an essential *constituent of living ctll.* Every living cell possesses a good amount of water.

(2) **Solvent action :** Water has got an important physiological functions of *solvent action.* By this action it serves as a medium in which the intra—and extra-cellular chemical action takes place.

(3) **Medium for physical processes :** Water acts as a medium for various physical processes like osmosis, diffusion, filtration, etc,

(4) **Carrier mechanism :** Water acts as a *'carrier'* in transporting foods to tissues and carrying wastes form tissues.

(5) **Body temperature regulation :** The normal body temperature is regulated by water by the following mechanisms : (a) *Heat gained* by the oxidation of food stuffs in the body. (b) *Heat loss* through urine and faeces (1·8%), Warming of expired air (3·5%) Vaporisation from lungs (7·2%) Evaporation from skin (14·2%) and radiation and conduction from skin (73%) :

(6) **Purpose of Hydrolysis :** Water serves the purpose of hydrolysis. It is an important chemical process involved in digestion and metabolism.

(7) **Dehydration :** Water serves the function of dehydration. If insufficient water is consumed, some electrolyte must be eliminated so as to maintain the ionic concentrations of the body fluids. From this, it also follows that the removal or loss of electrolyte requires the removal of some water.

(8) **Ionising medium :** Water is a very good ionising medium. When the dielectric constant of water being very high, oppositely charged ions can co-exist in water without any remarkable change.

(9) **Vehicle for physiological prcesses :** Water acts as a vehicle for various physiological processes such as absorption

of food material from the intestine, reabsorption form kidney tubules, transport of the intestine, reabsorption form kidney tubules, transport of the various foodstuffs from one place to the other, drainage and excretion of metabolised end products, manufacture of various secretions of digestive juices and carrying the hormones to different places of activity.

(10) **Lubricating action :** Water acts as a lubricant and mobilising action to prevent friction and drying.

(11) **Refractive medium :** Water present in the aqueous humour, acts as a refractive medium for light.

(12) **Respiratory function :** Carbon dioxide and Oxygen are slightly soluble in water that help in the process of gaseous exchange in the tissues and lungs. The fishes take oxygen from dissolved oxygen in water.

(13) **Mechanical action :** The cerebrospinal fluid that contains nearly 99% water that acts as a mechanical buffer preventing shock and injury to the nervous system.

Q, 24. Write short notes on :

(1) **Ketone Bodies** : These are ketone acid which are aceto-acetic acid, acetone and β-hydroxy butyric acid that are derived from acetoacetic acid. *Sites of Origin* : (i) Liver is the most important place of production of ketone bodies. (ii) Little amount of ketone bodies are produced from kidneys, lungs, skeletal muscles, brain, spleen and testis. (iii) The striated muscle, heart and the organs drained by the portal vein occasionally added small amounts of ketone bodies. *Functions* : (i) Ketone bodies provide a source of energy for tissues when the supply of carbohydrate is restricted. (ii) The tissues of the diabetic animal can oxidise completely the ketone bodies even if no sugar is buring.

(2) **Ketosis** : In certain conditions, products of fatty acid metabolism, aceto-acetic acid, β-hydroxybutyric acid and acetone, accumulate in the blood and are excreted in the urine, a condition that is called ketosis. *Effects of Ketosis* : (i) Ketone bodies provide a source of energy for tissues when the utilisation of carbohydrate is imparied. (ii) In severe ketosis there may be a dangerous disturbance in acid-base equilibrium. (iii) Ketosis leads to acidosis and dehydration.

(3) **Blood Calcium :** The calcium in the blood is almost entirely in the plasma. The normal level of blood calcium is 9 to 11·5 mg. per 100 ml. *Forms of Blood Calcium* : Calcium in the blood exist in two forms such as diffusible and non-diffusible forms. (i) The total amount of diffusible blood calcium is 5 to

6·5 mg. per 100 ml. It is present in the blood as ionised and non-ionised calcium. (iii) The total amount of non-diffusible calcium is 4·5 mg. per 100 ml. of blood.

(4) **Deamination :** It is the process by which the amino-radicle ($-NH_2$) is removed from amino-acids. It takes place in the liver with the help of an enzyme known as deaminase. By the deamination process, amino-acid molecule is broken down into amino-part and non-amino part. *Sites* : (i) Liver is responsible for most of the deamination of amino-acids. (ii) Kidney as well as liver are very active in the deamination process. *Mechanism* : The mechanism of oxidative deamination process is done by flavoprotein enzyme, glutamic acid and glycine.

(5) **Uric acid :** It is the final end product of purine metabolism in man and is excreted in urine. It is a transparent crystalline powder, practically insoluble in cold water aad easily soluble in alkalies. It is insoluble in alcohol and ether in pure state found in normal human urine, human blood and alse occurs to a much larger extent in the excrement of birds and reptiles. *Formation* : The purine nitrogenous base contains adenine and guanine which forms uric acid after chemical reactions forming hypoxanthine and xanthine.

(6) **Glycogenesis** : It is a process for the formation of glycogen from glucose that takes place both in the liver and in the muscle. **Formation** : (i) *In the Liver* : Glucose combines with phosphoric acid and forms glucose$-1-PO_4$. Then it combines with phosphoric acid and forms glucose 1 : 6 diphosphate which ultimately converts into glycogen. (ii) *In the Muscle* : Glucose forms glusose$-6-PO_4$, then glucose$-1-PO_4$ and ultimately forms glycogen.

(7) **Neoglucogenesis :** It is a process by.means of which liver glycogen can be built up from non-carbohydrate precursor which are converted first into glucose and then into glycogen. **Formation :** (i) *From Protein* : Certain anti-ketogenic amino-acids after deamination yield keto-acids which can built up liver glycogen. (ii) *From Fat* : Glucose may be formed from fat in every small amount by many of the organic acids involved in the citric acid cycle.

(8) **Omega Oxidation of fatty acids :** It is the most important theory of fatty acid oxidation which merely acts in a supplementary manner. **History :** Verkade, Flaschentrager and others have established this theory in 1938. **Materials Required :** Palmitic acid containing 16 carbon atoms is taken for omega oxidation. **Conditions for Oxidation :** The condition for omega oxidation of fatty acids are as follows : (i) The terminal methyl group (omega position) may be first oxidised to carboxyl

group. (ii) β-oxidation proceeds from both ends and converts into carbon monoxide. (iii) The subsequent hydrolysis takes place. **Results :** From omega oxidation theory of palmitic acid we get 6 mols. of Acetic acid and one molecule of Di-carboxylic acid.

(9) **Basal Metabolic Rate :** The basal metabolic rate is the energy output of an individual under standardized resting condition. i.e. at complete bodily and mental rest under comfortable conditions of temperature, pressure and humidity, 15 to 18 hours after a meal i.e. post-absorptive period. In adult male, it is about 40 Calories per sq. metre of body surface per hour and in adult female, it is about 37 Calories. **Factors modifying B.M.R. :** (*a*) *Physical factors* : These are Surface area, Age, Intake of food, Muscular work, Starvation etc. (b) *Hormonal factors* : These are Thyroxine, Adrenaline, Pituitarin etc. (*c*) *Enviornmental factors* : These are Body temperature, External temperature, Barometric pressure, etc. (d) *Sexological factors* : These are Pregnancy, Sex etc. **Methods of determination of B M.R.** (i) The direct method will be by Atwater-Benedict's respiration Calorimeter. (ii) The indirect method will be by Surface area, by Pulse Rate and Pulse Pressure and by Benedict's Roth apparatus.

CHAPTER FIVE

NUTRITION AND DIETETICS

Introduction : In 1911, *Dr. Casimir Funk*, obtained a crystalline substance from rice polishings and he named the substance Vitamine. Vitamine comes form the word, Vit (vitality) and Amine (group). All the Vitamins which was discovered later on are not amine in nature but some are protein and some are lipide in nature. So there arises a good deal of opposition against the name of Vitamine. So, 'e' of the amine group is omitted and the general term Vitamin was agreed upon. The individual Vitamins being designated by letters of of the alphabet. The following is the classification of the known Vitamins.

I. *Fat soluble Vitamins* : These are Vit. A, Vit. D, Vit. E and Vit. K.

II. *Water soluble Vitaminas* : These are Vitamin B complex (B_1, B_2, B_6, B_{12} etc), Vit. C and Vit. P.

III. *Soluble both by water and fat solvent* : These are Vit. K and Anti-aminotropic factor.

Q. 1. What are the essential constituents of diet ? Prepare a balanced diet chart of mixed food containing 3000 Calories per day.

A consideration of the subject of diet with special reference to India and the tropics in general is somewhat complicated. In the first place in a country inhabited by different peoples of different nationalities, castes and creeds, food habits differ markedly and the evidence indeed of the tenacity of original cultures carried over in the process of immigration from distant areas. It is a more important point whether man all over the world requires fundamentally a similar diet or whether adoptation to climate involves an altered dietary regime.

Essential Constituents of Diet : The normal diet must have the following qualities : (a) Preparation of different food stuffs as for protein, fat and carbohydrates from which the calori requirement is satisfied. (b) Different amino-acids that will make up the food proteins. (c) Minerals. (d) Vitamins. (e) Water.

I. **Protein** : The daily requirement of protein is one gm. per. kilogram of the body weight. Both animal or first class protein should be taken with the diet. The first class proteins contain all the essential amino-acids and greatly help in the growth of the tissues. The second class proteins do not contain the essential amino-acids and are utilized to supply the energy in the body. The proteins are taken to replace the wear and tear of tissue to help in the growth of the tissues of the growing children and to supply energy in the body.

II. **Fats** : The daily requirement of fat is 1 gm per kg. of body weight. Fats are taken to help in the growth of the tissues, to supply the fat soluble vitamins and to supply energy in the body. The fats are also stored in the body as depot fat which are utilized during starvation. The part of the fat should be of animal origin because animal fat supplying Vit A and D and they also supplying adequate amount of essential fatty acids.

III. **Carbohydrates** : The daily requirement of carbohydrate is 5 gm. per kg. of body weight. The carbohydrates are taken to supply the energy in the body. 80% to 90% of the energy is derived by the oxidation of carbohydrates. The carbohydrates are also taken to maintain a normal blood sugar level and to prevent the ketosis in the blood.

IV. **Amino-acid** : Protein should contain essential amino-acids in adequate quantities as Arginine, Histidine, Threonine, Valine, Isoleusine, Lysine, Methionine, Phenyl-alanine, Leucine, and Tryptophane.

V. **Minerals** : They are absolutely essential in the body. Calcium is essential for the contractility of the cardiac muscle and the coagulation of blood. Sodium is essential for the maintenance of crystalloid osmotic pressure of blood for excitability of the tissues. Potassium is essential for the maintenance of intra-cellular osmotic pressure and for the initiation of the impulse in the muscles and nerves. Iron, copper, cobalt, nickel and manganeese are essential for the synthesis of hæmoglobin. Iodine is essential for the synthesis of thyroxine. Calcium and mangnesium stimulate the activity of the enzymes and they act as activators.

VI. **Vitamins** : These are the accessory food stuffs which are essential for the growth of different tissues, Most of the ingredients of the Vit. B complex act as enzyme or co-enzymes and thereby help in the oxidation and reduction processes of the food stuffs in the tissues. Vitamin B_{12}, folic acid and Vitamin C help in the development of red blood cells and also help in the synthesis of hæmoglobin. Vitamin E acts as a sterility factor and prevents sterility of an individiual. Vitamin K helps in the coagulation of blood by performing the formation of prothrombin in the liver.

VII. **Water** : It is absolutely essential to maintain the normal water balance of the body and to maintain the blood volume. The amount of water lost through the different excretory channels must be fulfilled by the intake of water for the proper growth of the tissue and for the normal activities of the different tissues, water is absolutely essential.

Preparation of Balanced Diet Chart :

Taking the average height of an Indian male adult is 5 ft. 5 in i.e. 164 C.m. and normal weight be 75 kg., then the total area would be 1·8 sq. metres.

Taking B.M.R. be 40 calories per hour per sq. metre. 24 hours are divided into three groups such as 8 hours sleep, 8 hours awake and 8 hours moderate work.

In 8 hours Sleep : The amount of heat produced in the body during 8 hours sleep = 40 Calories × 8 hours × 1·8 sq. meter = 576 Calories.

In 8 hours Awake : The amount of heat produced in the body during 8 hours awake = Basal heat + 30% more = 576 Cal. + 172·8 Cal = 748·8 Calories.

In 8 hours Moderate Work : The amount of heat produced in the body during 8 hours moderate work = Basal heat + 1000 Calories = 576 Cals. + 1000 Cals = 1576 Calories.

Therefore, total heat produced in the body in 24 hours = 576 + 748·8 + 1576 Cals. = 2900·8 Cals. or approximately 3000 Cals.

This amount of heat is derived by the oxidation of proteins, fats and carbohydrates. One gram of carbohydrate and protein liberate 4·1 Cal. of heat separately but one gram of fat liberates 9·3 Cal. of heat.

(a) Protein requirement and the heat derived from protein : 1 gm. per kg. of body weight.

∴ Total amount of protein to be taken = 75 gms.

Heat generated by protein = 75 × 4·1 Cals.
= 307·5 Cals.

(b) Fat requirement and the amount of heat derived from fat :

1 gm. per kg. of body weight.

∴ Total amount of fat to be taken = 75 gms.

Heat generated by fats = 75 × 9·3 Cals = 697·5 Cals.

(c) Carbohydrate requirements and the amount of heat derived from carbohydrate :

307·5 Cals + 697·5 Cals + Carbohydrate requirement = 3000 Cals.

∴ Carbohydrate requirement = 3000 − (307·5 + 697·5) Cals
= 3000 − 1005 Cals.
= 1995 Cals.

Cals. of heat is derived from 1 gm of Carbohydrate. 1995 Cals. of heat is derived from = 1995/4 = 448·7 gms.
or, 500 gms. (approx).

Q. 2. Describe the sources, properties, deficiency signs, functions and daily requirements of Vitamin A.

Vitamin A is known as Anti-Xerophthalmic factor because it prevents a number of cases of eye lesions. It was discovered as a result of the investigations of *Hopkins* in England and *Osborne*, *Mendel*, *Mc. Collum* and *Davis* in America.

Sources of Vitamin A :

(a) **Animal sources :** Mammalian and fish liver, egg yolk, butter, cream, codliver oil has a very high Vitamin A content and Halibut oil, a much higher one. Lard and beef fat are poor sources of Vitamin A.

(b) **Vegetable sources :** Vegetable oils with the exception of corn oil and red palm oil contain little or none. Cereals, with the exception of maize, are relatively poor in Vitamin A. In plant, the sweet potato is a good source of Vitamin A. The outer green leaves of lettuce, carrots, yellow maize, spinach, green peas, bananas are rich in Vitamin A.

Component : There are two components of Vitamin A known as vitamin A_1 and vitamin A_2.

Properties : (1) Vitamin A is soluble in fats and fat solvents. It is present in the unsaponifiable fraction of the fat. (3) It is resistant to heat in absence of air but is readily destroyed by oxidation at all temperature. (4) Though colourless itself, it gives a blue colour with antimony trichloride in the presence of oxygen. (5) In oily solution, Vitamin A or its esters in alcoholic solution, show a green fluorescence when exposed to ultraviolet light.

Deficiency signs : There are a number of manifestations of Vitamin A which are the following :

I. Eye Lesions *:*

(1) **Nyctalopia** or *functional hemeralopia* or *night-blindness :* This is failure of vision in dim light which occurs in man and animals as a result of Vitamin A deficiency. The process by which the visual purple and other pigments in the eye are elaborated from Vitamin A, has been studied by *Wald* and by *Hecht* and his associates. Vitamin A is tranported to the retina by blood where it combines with the protein to form visual purple which, as a result of photochemical action of light is then converted into visual yellow. The latter breaks up again or Vitamin A is discharged almost wholly. So, Vitamin A in the diet is essential to help in the process of complete degeneration of the visual purple in the retina.

(2) **Xerophthalmia** or *dry eye* **:** It is an inflammatory eye condition where a whitish deposits known as "*Bitot*" *spot*" appeared on the scleral conjuctiva, due to atrophy of epithelial

cells and keratinisation. In xerophthalmia, the lacrymal secretion from the lacrymal glands is suppressed, corneal surface becomes dry and having lost the protective and lubricating effect of the tears, becomes invaded by micro-organisms.

(3) **Keratomalacia** : It results from prolonged and severe Vitamin A deficiency. There will be an inflammation and thickening of the conjunctivae with a purulent discharge and softening leading to ulceration of the cornea.

II. **Epithelial Tissue Lesions** :

(1) **Dermatoses** or Disorders of the skin : It is a condition of the skin where dryness or scaliness is localised due to the suppression of the sweat gland. The keratosis of the hair follicles are specially found on the extensor surface of the upper and lower extremities, shoulders, neck and back region.

(2) **Cornification of Epithelial surfaces** : The epithelial linings of the respiratory, alimentary and urinary tract and the ducts of various glands, tend to become converted to the stratified squamous epithelium with cnnsequent drying up of their secretions. There will be a general tendency toward conification of epithelial tissues llke lacrymal glands, hair follicles and cutaneous glands when the diet is deficient in Vitamin A.

(3) **Keratinisation and degeneration** : The keratinisation and degeneration of the epithelium are evident in the respiratory and gastro-inestinal tracts leading to irritation, ulceration and dysfunction and easy access of infection.

III. **Degenerative changes in the Nervous tissue** : There will be the degeneration of the nervous system due to the defective nutrition of the nerve fibres and cells. The extensive degenerative changes in the ganglia, nerves and nerve cells, organs of both hearing and balance inside the temporal bone lead to incoordination of movement, stiffness, weakness, mental dullness, convulsions and deafness.

IV. **Maldevelopment of Bone** : Vitamin A is an essential dietary constitutents for the normal and oderly development of bony structures. The cancellous tissue is gaeatly thickened and the entire bone is shapeless. There is an osseous deformities in the cranial bone and vertebral column. Vitamin A exerts a specific action upon the osteoblasts and osteoclasts of the growing bone.

V. **Reproductive System** : Due to the deficiency of Vitamin A, degeneration, cornification of epithelial tissue of the genital tracts, functional amenorrhoea, impotency and degereration of the seminiferous tubule.

Physiologic Function of Vitamin A : (1) It is essential for growth, being responsible for the specific synthesis of all tissue elements in the body where sterol metabolism is active.

(2) It is essential for the integrity of the epithelial tissues everywhere including cornea and conjuctiva. (3) It serves as a carrier of specific proteins to place for special processes as the formation of visual purple and then the release to visual yellow. (4) It is intimately related to sterol metabolism. (5) It is related to the specific synthesis of the tissues of the muscles and glands and in haemopoiesis.

Daily Requirements : The daily Vitamin A requirment for about in man is from 5000 to 6000 International Units and from 1500 (under 1 year) to 5000 (at 15 years).

Q. 3. Describe the sources, properties, functions, deficiency signs and daily requirements of Vitamin B_1 (Thiamine or Aneurine)

Vitamin B_1 is known as Thiamine or Anti-neuritic or Aneurine or Anti-beriberi Vitamin and its absence from the diet was shown to be the cause of Beri-beri.

Sources :

(*a*) **Richest Sources :** The Vitamin B_1 is found either as the phrophosphate (cocarboxylase) or in the free form are liver, kidney, lean pork, brewer's yeast, germ of wheat, oatmeal, rice polishings, bran, soy bean, peanuts, peas and beans.

(*b*) **Poor Sources :** (1) The smaller amounts of vitamin B_1 are present in egg-yolk, milk, potatoes, 'corn meal, turnips, banannas and various nut kernels. (2) It occurs in the tissues both as the free base and as the pyrophosphate, which is known as cocarboxylase.

Properties : (1) It is soluble in water and relatively thermolabile. (2) It can stand on cooking or boiling at 100°C for a short period but there is rapid destruction if boiled for longer time or if autoclaved at 120°C. (3) It withstands drying, picking or canning winhout loss of potency, if done without contact with air. (4) The alkalies lead to its oxidation to thiochrome giving a blue fluoresence in ultraviolet light. (5) In dried form it stands heat better. (6) The aqueous solution (1 in 20) has a ph. of 3·5. 7) Presence of alkalies hastens the rate of destruction when exposed to heat. (8) It is resistant to strong acids but is readily destroyed by alkali, being hydrolysed into its constituent pyrimidine and thiazole rings. (9) It is absorbed from solution by Fuller's earth.

Functions (Physiological Actions) : (1) Vitamin B_1 is essential in crbohydrate metabolism, acting as carboxylase, the co-enzyme is thiamine pyrophosphate. (2) It aids in oxidative removal of pyruvic and lactic acids which are intermediate products of glucose to carbon dioxide and water. (3) In the absence of Vitamin B_1, there is more accumulation of pyruvic and lactic acid in the blood and tissues leading to disturbance of the neuro-muscular mechanism. (4) It is regarded as an important item in cell-respiration. (5) The intestinal bacteria are capaple of synthesising thiamine in the intestines, which again the bacteria utilise for their own nourishment and growth. (6) It is responsible for the synthesis of fats from carbohydrates and proteins. (7) It helps for the oxidative decarboxylation of pyruvic acid (8) It is essential for the oxidation of sugar in the tissues and brain.

Deficiency Signs : (1) **Beri-beri** (Polyneurities) is characterised by inflammation of the peripheral nerves which leads to progressive paralysis of the limbs and sensory disturbances, dilatation of the right heart, low oxygen consumption of the brain tissue, accumulation of lactic acid in the hind-brain, liver, heart and hyperglycamia and depletion of liver glycogen occur in polyneuritic pigeons. (2) **Arrested growth :** Loss of appetite leads to undernutrition is however a contibutory factor in the retardation of growth resulting from a deficiency of this Vitamin. (3) **Loss of appetite and atony of the gastro-intestinal tract :** It is an early effect of Viuamin B_1 deficiency. In occurs in rats and dogs and in human beri-beri. The anorexia is secondary to a relaxed state of the gastro-intestinal musculature and the reduction in motor activity of the gastro-intestinal tract. (4) **Bradycardia :** It is found in rats and pigeons. Marked cardiac slowing was observed in pigeons fed upon polished rice and it is abolished by vagal section or atropinization. (5) **Personality Changes :** Thiamine deficiency of a degree may result in psychic changes such as depression, irritability, quarrelsomeness, anxiety or fearfulness.

Daily Requirement : The daily adult human requirement is around 0·6 mg. per 1000 Calories of diet. The requirement is increased during the actively growing period, in pregnancy and lactation and on a high carbohydrate diet.

Q. 4. What do you know about Thiamine deficiency ?

Thiamine hydrochloride is a white crystalline compound, water soluble, labile Vitamins falls under the group Vitamin B complex, found in yeast, green vegetables, e.g-yolk etc.

Signs and Symptoms of Thiamine deficiency :

Thiamine hydrochloride is a white crystalline compound, water soluble, labile Vitamin falls under the group Vitamin B complex, found in yeast, green vegetables, egg-yolk etc.

Signs and Symptoms of Thiamine deficiency:

(a) **Arrested growth :** Due to thiamine deficiency the normal growth in young individual has been arrested Loss of appetite which leads to under nutrition is however a contributory factor.

(b) **Loss of appetite and atony of the gastro-intestinal tract :** The loss of appetite is an early effect of Vitamin B_1 deficiency. There will be loss of tone of the gastro-intestinal tract which diminish gastric secretion.

(c) **Bradycardia :** It occurs only in rats and pigeons. The heart becomes weak and enlarged due to the accumulation of lactic acid and pyruvic acid causing slowness of the heart.

(d) **Blood changes :** The lactic acid and pyruvic acid are accumulated in the blood.

(e) **Personality changes :** Thiamine deficiency of a degree may result in psychic changes such as depression, irritability, quarrelsomeness, anxiety or fearfullness.

(f) **Beri-Beri :** Though it is a multiple Vitamin deficiency disease but it is generally cause due to the deficiency of thiamine along with inadequency of other Vitamins and porteins, fats, minerals and salts. This disease in characterised by inflammation of the peripheral nerves that lead to progressive paralysis of the limbs, sensory disturbances and dilatation of the right heart occurs. The chief characteristics of Beri-Beri are the following :

(i) *Cardiac damage* : Enlargement of the heart, pulse rate rapid and feeble, presence of cardiac oedema are caused due to an increase in weight of the right ventricle causing signs of circulatoy failure.

(ii) *Inflammatory changes* : The inflammatory changes take place in the wall of stomach and duodenum.

(iii) *Circulatory change :* Dilatation of the heart, rapid and feeble pulse, cardiac oedema and accumulation of lactic acid in the cardiac muscle are the chief characteristic of the circulatory changes.

(iv) *Eye changes* : There will be nystagmus where a jerky movement of the eye ball regularly occurs due to fatigue of the extra-ocular mucles.

(v) *Polyneurities* : In this case, degeneration occurs in the peripheral nerves and in the central nervous system specially in the anterior horn cells of the spinal cord. There will be retraction of the head, paralysis of the limbs, tenderness of the skin, muscles and bones and loss of deep reflexes.

(vi) *Brain changes* : There will be accumulation of lactic acid in the hind brain causing retraction of head.

(vii) *Muscular weakness* : There will be diminution and loss of deep reflexes and wasting and paralysis of the muscles.

(viii) *General Changes* : There is loss of appetite, nausea and vomiting.

(ix) *Mental changes :* The patient suffers from sleeplessness and becomes anxious and depressd.

Q. 5. Descibe the sources, properties, functions, deficiency signs and daily requirements of Vitamin B_2 or Riboflavin.

Vitamin B_2 or Riboflavin or Lactoflavin is a water soluble Vitamin. It is found in the yeast, liver, kidney, milk, egg, meat etc.

Sources : (a) *Plant Sources :* Vitamin B_2 is found in yeast, wheat germ, green vegetables etc. (b) *Animal Sources :* Riboflavin contains in good amount in the liver, kidney, milk, egg, meat etc,

Properties : (1) Riboflavin crystallises from dilute acetic acid, alcohol or pyridine in fine orange-yellow needles. (2) It is a yellowish green pigment slightly soluble in water and is insoluble in ether, chloroform and benzene. (3) It is realitively stable under ordinary cooking conditions but is less stable to bright sunlight than many other Vitamins.

Functions : (1) Riboflavin is essential for body growth. (2) It is in the prosthetic group of so many enzyme systems catalyzing important transformations. (3) It is one of the major component of yellow enzyme of Warburg and essential for tissue oxidation. (4) Both FMN andFADN after combining with protein, forms apoenzyme that play a major role in a number of enzyme system. (5) It regulates the functions of some endrocrine organs particularly those which are connected with carbohydrate metabolism. (6) When light falls on retina, riboflavin is transformed into a compound that stimulates optic nerve.

Dificiency Signs : (1) **Cheilosis :** It is a condition when fissures are developed in the lips and at the corners of the mouth. (2) **Angular Stomatitis :** It is a condition of fissures at the angle of the junction of the two lips on both sides of the mouth. (3) **Glossitis :** It is a condition of sore tongue. (4) **Skin :** A seborrhóic dermatits effects specially the ears, nose, forehead of the face. There will be loss of hair, skin becomes dry and scaly and liability to infection. (5) **Arrseted Growth :** The growth of the body becomes arrested. (6) **Eye Lesions :** Due to lack of riboflavin, capillary loops extend into the cornea the eye becomes itchy, light sensitive i.e. *Photophobia*, vision is poor in dim light and in time the *corneal vascularisation* may lead to severe *interstitial keratities.*

Daily Requirement : The minimum intake of riboflavin in adult for maintenance of health lies between 1·5 and 3 mgm per day. The daily requirement of riboflavin can be calculated in terms of protein intake becomes 1·125 mgm. of riboflavin per 1 gm. of protein.

Q. 6. Describe the sources, chemistry, properties. functions, deficiency signs and daily requirements of Vitamin B_{12} or Cyanocobalamin.

Vitamin B_{12} or Cyanocobalamin is a water soluble Vitamin, found in liver, kidney, pancreas, meat, egg, etc. and its absence from the diet was shown to be the cause of Pernecious anaemia.

Sources : Vitamin B_{12} is found in Mammalian muscle (horse meat, beef, pork, mutton), Liver, Kidney, Pancreas, Egg yolk, Milk, Cheese, Milk powder and Crue casein.

Properties : Vitamin B_{12} is soluble in water. (2) It is liquified in 210° to 220°C but it is completely liquified in at 300°C. (3) Keeping their Vitamin value in watery solution, it maintains a natural PH. (5) It is acidic of 4·5 Ph. With alkali, this Vitamin value will be desaurate. (5) One atom of nitrogen combines with one atom of carbon to form cyanogen molecule. It is poisonous but due to the presence of cobalt, it converts into non-piosonous form.

Functions : (1) Vitamin B_{12} is important for hematopoiesis and thereby helps in the formation and maturation of red blood cells. (2) It promotes the growth of certain bacteria. (3) It serves as a growth factor for higher animal including man. (4) It influences upon the metabolism on sulphur containing amino-acids. (5) It is essential for the synthesis of Ribonucleic acid which would account for neurological defects in pernecious anaemia and for the abnormalities of certain epithelial surface such as that of the tongue and failure in erythrocytic maturation.

Deficiency Signs : (1) **Pernicious Anaemia :** It occurs in the human being when Vitamin B_{12} is deficient. (2) **Degenerative changes :** There will be degenerative changes in the taste bud and the tongue. The spinal cord suffered from degenerative changes particularly the posterior horn cells which can be cured by months of treatment with Vitamin B_{12}. (3) There will be **nutritional macrocytic anaemia**. (4) There will be severe **neurologic involvement** due to lack of Vitamin B_{12}.

Daily Requirement : The minimum dose of cyanocobalamin for maintenance of health becomes 10 to 12 mgm. per day.

Q. 7. Describe the sources, properities, dificiency signs, functions and daily requirements of Vitamin C.

Vitamin C or ascorbic acid is known as anti-scorbutic Vitamin because it prevents to occur scurvy disease. This is isolated by *Szent-Gyorgyi* in 1928 and synthesized by *ReichStein* in 1933.

Sources : (a) *Vegetable sources* : Orange, tomato, banana. amloke, green mango, lemon, etc, are rich sources of Vitamin C.

(b) *Animal sources* : Supra-renal cortex, corpus luteum, mother's milk and cow's milk contain a good amount of Vitamin C.

Properties : (1) It is white crystalline compound, solouble in water, in soluble in fats and oils. (2) The synthetic preparation is known as ascorbic acid. (3) It may be dextro-or levorotatory. (4) It is very sensitive to oxidation particulary in the presence of copper ions. (5) It is almost stable in weak acid solution but readily detroyed in alkaline media. (6) It is destroyed by prolonged heating or cooking but it can be preserved for a long time anaerobically.

Deficiency signs : Ascorbic acid deficiency leads to a disease known as **scurvy**. In this type of disease, there will be the failure to deposit intercellular cement substance like collagen osteoid and dentine, swelling and tenderness in bones and joints, enlargment of the junction oƖ the ribs and bone lesions and haemorrhages of the gums and loosening or breaking of the toe teeth, subcutaneous haemorrhage upon mild injury, dyspnoea, oedema and anaemia. A loss of weight and a marked pallor are also noted. In infant the symptoms include irritability, fretfulness, tendeness, swelling of joints, degree of apathy and pallor and a desire to remain quite motionless.

Physiologic functions : (1) Ascorbic acid is intimetely concerned in the normal production of suporting tissues like osteoid, dentine and collagen which are mesenchymal in origin. (2) It takes part in oxidation reduction system, probably by acting as hydrogen transporter. (3) It increases iron absorption from the intestine of the humans and animal. (4) It is essential for the proper formation of fibroblasts, osteoblasts etc. (5) It takes part in the formation of red cells,haemoglobin and platelets. (6) It has been implicated in the enzymatic oxidation of D.P.N.H. (7) It helps in the development of the protein matrix and deposition of Calcium and Phosphate in the bones. (8) It plays an important role in wonnd repair. (9) It helps in the conversion of folic acid to folinic acid. (10) It has some role in enhancing the resistanceof animals against different toxins.

Daily Requirements : The human requirement of ascorbic acid becomes 75 mg. for adults, 100 to 150 mgm. during pregnancy and lactation and 30 to 75 mg. for children upto 12 years of age.

Q. 8. Describe the sources, properties, deficiency sign, functions and daily requirements of Vitamin D.

Vitamin D or Anti-rachaetic factors that prevents ricket is children, osteomalacia in adults and dental caries in younger individuals.

Sources : (a) *Animal sources* : Halibut liver oil, cod liver oil and the liver oils of bony and cartilagenous fishes has a very high source of Vitamin D. The egg yolk, butter, cream and milk are also the animal sources of Vitamin D. (b) *Vegetable sources* : The vegetables food like green vegetables and cotton seed oil are poor sources of Vitamin D.

Components : There are a number of components of Vitamin D which are Vitamin D_1 or Ergosterol, Vitamin D_2 or Calciferol, Vitamin D_3 or 7-dehydro-cholesterol, Vitamin D_4 or 22-dehydro-cholesterol and Vitamin D_5 or 7-dehydro-sitosterol.

Properties : (1) Vitamin D is soluble in fats, oils, ether and alcohol but insoluble in water and could be extracted with fat solvent. (2) It is very stable to heat and to oxidation. According to *Drawmon*, Vitamin D is thermostable and so it is not destroyed by heat and in presence of oxygen. (3) It shows an absoption band between 260 and 270 $m\mu$. (4) It stands in heat, alkalies and oxidation longer than vitamin A.

Deficiency sings : Vitamin D is indespensable to the normal calcification of bone. Its absence from the diet is followed by the development of the ricket in adult or of osteomalacia in females.

(a) **Rickets :** (1) Disturbance of calcium-phosphorus metabolism with consequent defective ossification. (2) Development of various deformities like Knock knees, Bow legs, enlargement of the epiphyses, spinal curvature (scoliosis), malformation of the chest, contracted pelvis, soft depressable areas in the parietal bones and the development of bosses on the temporal bones. (3) The natural curvatures of the long bones tend to become exaggerated. (4) The enlargements of the costo-sternal junctions of the ribs causing a series of small swelling of the ribs on either side of the thorax which is referred as *rachetic rosary*. (5) Dentition is usually dealyed and sweating of the scalp is common.

(h) **Osteomalacia :** It is a fault of ossification generally occuring in adults but specially in women. Pathologically, it is simply adult rickets. The chief characteristics are : (1) The entire bone if softer than the ordinary rickety bone. (2) The calcium shows a greater decrease than does the phosphorus and the calcium phosphorus ratio is reduced. (3) The magnesium content is increased but blood calcium is lowered and *tetany* in consequence is a frequent complication. (4) The softness and pliability of the bones lead to deformity is an extreme degree. (5) Pelvic abnormalities create serious hazards during child birth.

(c) **Dental Caries :** It is a type of Vitamin D deficient disease localised in the teeth. The chief characteristics are :

(1) Delay in the eruption of the permanent teeth. (2) Thickening of the bony tissues of the jaws and irregularity in arrngement of teeth. (3) Poorly calcified enamel which show pitting, grooving and pigmentation.

Physiologic functions : (1) Vitamin D controls the deposition af calcium and phosphorous in the tissues and thereby it plays an important role in normal bone and teeth formation and in the maintainance of normal structure. (2) It promotes the absorption of calcium and phosphorous for the bowels and acts as an ecnomiser in the form of storage and also a mobilizer in times of need, in the latter months of pregnancy and during lactation. (3) It is storable to some extent and is absorbed through bile slats. (4) This vitamin attacks the tissue prospholipids and liberates their phosphoric acids.

Daily Requirements : One I.U. is equal to 0'025 μg. of pure crystalline Vitamin D_3. The infant and children require 400 I.U. daily. The pragnant and lactating mother also require 400 I. U. daily.

Q. 9. Describe the sources, properties, deficiency signs, functions and daily requirements of Vitamin E.

Vitamin E in known as Anti-sterility Vitamin or Fertility Vitamin. It is discovered by *Bishop* and *Evans* in 1922 and this Vitamin maintains the normal productive power of an individual, Without it in the diet normal development of spermatozoa in the testis (spermatogenesis), normal prgenancy and lactation and viability of the progeny is impossible.

Sources : The sources of Vitamin E are :

(a) **Vegetable sources** : The chief sources of Vitamin E are found in the green vegetables such as lettuce, peas, alfaalfa and germ of various and seeds wheat germ oil.

(b) **Animal sources** : Vitamin E is present in the meat of just born animal, yellow portion of the egg and the growing embryo of the uterus.

(c) **Natural sources** : Vitamin E is found in the lipid substance and its esters.

Properties : (1) The tocopherols are liquids, light yellow in colour, stable to heat and acids but unstable to alkalies and soluble in fat and fat solvent. (2) It is easily oxidisable, oxidation lower or destroys their biological value and it is destroyed by ultra-violet rays. (3) There are seven known naturally occuring tocopherols and out of them alpha-tocopherol is the most potent one (4) The tocopherols are excellent anti-oxidants and their property rest in the hydroxyl group and assume a great importance from a physiologic stand point.

Dificiency signs : In man, Vitamin E deficiency symptoms are not well established but is seen in case of animals like rats

(A) **Sterility :** It occurs both in male and female individuals.

(a) **In Male :** In male rats on a Vitamin E deficient diet the loss of fertility is a progressive process. The different changes in the reproductive structures that occurs are the following : (1) In the earlier stages, the spermatozoa lose their motility, latter they fail to be produced. (2) Finally, the spermatogenic epithelium degenerates and sex instinct fails. (3) Atrophy of the seminiferous tubules takes place and cause impotency or sterility. (4) Cells once damaged, is not likely to be restored to normal by a diet rich in Vitamin E. (5) A decrease in the size of the testes and disturbance in the production of the sperm forming cells are encountered. (6) In servere cases the animals display no sexual desire.

(b) **In Female :** In this case, a peculiar type of sterility develops. The different manifestations of Vitamin E deficient animals are the follwing : (1)The oestrus cycle occurs normally in animals. (2) When fertilization occurs, the inplantation of the ovum is not prevented but the embryos offer developing for a short time die and are reabsorbed. (3) The mesodermal cell proliferation forms a ring in the blastoderm stage and cuts the embryo off from its blood supply by strangling the vessels and leads to intrauterine fœtal death.

(B) **Muscle Dystrophy :** It has been shown that Vitamin E is necessary for the mainatainace of structural architecture and functional value of smooth and skeletal muscles. The different manifestations of Vitamin E deficient animal are the following : (1) Vitamin E deficient mothers often show a spasticity of the hind limbs as early as the twenty-fifth day of life. (2) There will be hyaline degeneration and disappearance of striations in the muscles. (3) Leucocytes lnfiltration, proliferation of the sarcolemma nuclei and an increase in fat globules may be seen in Vitamin E dificient animals. (4) Creatine level becomes low in the muscle but urinary creatine increases and may reach fiften times than the normal level. (5) The muscular dystrophy, anæmia, leucocytosis and elevated excretion of creatine and allantoin and a reduced excretion of creatinine are found in case of Vitamin E deficient monkeys.

Physiologic functions : (1) Vitamin E prevents the sterility and maintains fertility of an animal. (2) It maintains the normal structural architecture and physiologic function of smooth and skeletal muscles. (3) The tocopherols seem to play an important part in oxidation-reduction changes in the body (4) It develops a temporary disturbance of œstrogenic equilibrium in the blood. Due to lackof Vitamin E, there will be hæmorrhagic detachment of maternal decidua that will lead to abortion. (5) It is capable of keeping the fluidity of blood and checks thrombosis in vein or in coronary arteries. (6) It is implicated in some way with the metabolism of the cell nucleus and thereby cells undergo rapid porliferation and maturation.

Daily Requirements : The human requirement for mixed natural tocopherols is about 30 mgm. per day.

Q. 10. **Describe the sources, properties. deficiency signs functions and dai y requirement of Vitamin K.**

Vitamin K or Anti-hæmorrhagic or Cogulations Vitamin that prevents hæmorrhage and helps in the process of coagulation, In 1935, *Dam* first proposed the term Vitamin K and it is isolated by *McKee* in 1939 and first synthesised by *Binkley* and *Fieser*.

Sources : The sources of Vitamin K are :

(a) **Vegetable sources :** Green leaves specially alfaalfa and other clovers, spinach, cauliflower and cabbage are the rich sources of Vitamin K. It is present in minimum amount in cereals, carrots, yeast and wheat germ, while little or none is present in potatoes and cod-liver oil.

(b) **Animal sources :** Vitamin K is present in salted fish and putrified meat.

(c) **Bacterial sources :** In the large intestine of human body, Vitamin K is formed by bacterial synthesis.

Components : The different components of Vitamin K are K_1, K_2 and K_3.

Properties : (1) It is a complex unsturated hydrocarbon and a derivative of napthoquinone. (2) It is highly sensitive to alkalies, light and exterme heat but when treated with alcoholic alkalies, it yields a beautiful but transient purple colour.

Deficiency sings : The lack of Vitamin K cause *haemorrhage* which produces a marked fall or lack of prothrombin of blood and thus renders blood less coagulable. The prothrombin level will be greatly diminished and bleeding will occur from the different parts of the body. The defective formation of prthrombin leads to hæmorrhagic diasthesis.

Physiologic functions : (1) Vitamin K is said to be essential of prothrombin in the liver and bile salts by hydrotrophy, help absorption from the bowel. (2) It maintains normal prothrombin level in blood and helps in blood coagulation. (3) It serves as the prosthetic group for the apoenzyme required for the mechanism involved in prothrombin synthesis. (4) It is implicated in electron transport and plays a role in oxidative phosphorylation.

Daily Requirement : "Dam unit" is the amount of Vitamin

K which is necessary to bring the clotting time of Vitamin K deficient chicks normal in 3 days. 20 Dam units could reduce the clotting time to normal in 6 hours. A"Doisy-Thayer unit" which equals 10 Dam units, is $\frac{1}{1000}$ the activity of 1 mg. of pure Vitamin K_1.

Q. 11. Describe the source, properties, functions, deficiency signs and daily requirement of Vitamin B_6 (Pyridoxine).

Vitamin B_6 or Pyridoxine or Anti-dermatitis factor, helps in the prevention of skin infections.

Sources : The sources of Vitamin B_6 are : (a) *Vegetable sources :* Germs of various grains and seeds, yeast, leafy vegetables, etc. (b) *Animal soucres* **:** Pyridoxine is present in the liver, egg-yolk, meat, kidney, etc.

Properties : (1) The Pyridoxine is converted in the organism into pyridoxal phosphate, the active group of a number of enzymes. (2) It is a white crystal and soluble in water. (3) It is a heat-stable in both acidic and alkaline solutions.

Physiologic functions : The functions of Vitamin B_6 are the following : (1) Vitamin B_6 takes part in normal tryptophan metabolism. (2) It acts as a prosthetic group for the transaminases enzymes. (3) Pyridoxine and its derivatives take part in the metabolism of amino-acids, i.e., in the transfer of the amino-group from one amino-acid to another and in amino-acid decarboxylation. (4) It is related to the formation of long chain polyunsaturated fatty acids. (5) It helps in the synthesis of fats from proteins and carbohydrates.

Deficiency Signs : The deficiency signs of Vitrmin B_6 are : (1) *Acrodynia*, a type of dematitis. (2) *Hypochromic anaemia*. (3) Reproductive failure. (4) Degeneration of the nerves. (5) Reduced growth of the body.

Daily Requirement : The daily requirement in pyridoxine in man is between 2 to 4 milligrams. In infants, it is 0·3 mgm. and in adults, it is 2 mgm. per day

Q. 12. Describe the sources, properties functions, deficiency signs and daily requirement of Folic Acid.

Folic acid is a water soluble vitamin and its deficiency leads to disturbances of blood formation, related to maturation of blood cell in the bone marrow and delayed release of cells into the blood.

Sources : The different sources of folic acid are **:** (a) *Vegetable source* **:** Folic acid in present in yeast, soyabeans, beans, green-leafy vegetables etc. (b) *Animal source* **:** Folic acid is found in liver, kidney, etc. (c) *Other sources* **:** Folic acid is prepared by the bacterial synthesis in the intestine.

Properties : (1) It is a yellow compound slightly soluble in water. (2) It is destroyed by light.

Physiological functions : (1) It helps in the synthesis of deoxyribonucleic acids in the cell nuclei. (2) It takes part in the formation and maturation of the red blood cells. (3) It is used for the treatment of Megaloblastic anaemia and Pernicious anaemia. (4) The reduced forms of folic acid act as a coenzyme in the transfer of formyl and hydroxymethyl groups in different biological systems.

Deficiency signs : The folic acid deficiency leads to : (a) **In Rats and Monkeys :** There will be arrested growth, anaemia, leukopenia (reduced leucocyte count) and agranulocytosis. (b) **In Man :** There will be Megaloblastic anaemia.

Daily Requirement : The daily requirement of folic acid in average adequate daily diet of adults becomes 50 microgram.

Q. 13. Describe the sources, properties, functions, deficiency signs and daily requirement of Nicotinic Acid.

Nicotinic acid or Pellagra-preventing factor or P-P factor, is a water soluble vitamin and its deficiency leads to *Pellagra* disease in man.

Sources : The different sources of Nicotinic acid are :

(a) **Vegetable sources :** Nicotinic acid is present in the husk of the cereals, pulses, bones, tomatoes, peas, yeast, etc.

(b) **Animal sources :** Meat, liver, fish, milk, etc. contain a good amount of nicotinic acid.

Properties (1) Nicotinic acid is a white crystalline substance. (2) It is heat stable and is moderately soluble in water. (3) It is not lost in cooking or canning.

Physiological functions : (1) It is a essential for normal growth of the body. (2) It takes an essential part in metabolism and tissue oxidation. (3) It helps in the convertion of fat from carbohydrates. (4) It prevents pellagra disease.

Deficiency signs : The deficiency signs of Nicotinic acid are the following :

(1) **Pellagra :** It is a type of dermatitis occur specially on the exposed parts of the body and seen in case of man. The characteristic features are : (i) The dematitis begins with *erythema* that resembles as sun-burnt areas. (ii) These areas gradually become reddish-brown, rough, scaly and keratotic. (iii) There will be gastro-intestinal disorder, polyneuritis and various forms of mental disorders.

(2) **Black tongue :** The tongue will be black in case of animal like dogs.

Daily Requirement : The daily requirement of nicotinic acid becomes 12 to 48 mgm. for adult males and little less in adult females.

SYNOPSIS OF VITAMINS

Name of Vitamins	Distribution	Deficiency Signs	Daily Requirment
Vitamin A (Anti-xerophthalmic factor)	Cod-liver oil, milk, butter, egg, fish, tomatoes, etc.	Night-blindness, xerophthalmia, Keratiusation of skin, Retard growth in Children etc.	Growing chilendren—6000 to 8000 I. U. and in adult, 5000 I. U.
Vitamin B Complex			
1· Thiamin B_1	Yeast, tomatoes, leafy vegetables, milk, egg, liver, Kidney, brain, etc.	Beri-beri.	In adult 1·8 mg.
2. Riboflavin B_2		Cheliosis, Angular, stomatitis, glossitis.	In adult, 1·5 to 1·8 mg.
3. Nicotinic acid		Dermatitis, Pellagra	In adult, 12-18 mg.
4. Pantothenic acid B_3		Alopecia, G. I. Tract disturbances	Daily diet contains 10 mg.
5. Folic acid		Anaemia, leukopenia, agranulocytosis.	Adult 50 micrograms
6. Cyanocobalamin B_{12}		Pernicious anaemia	1μ gm per day
Vitamin C (Ascorbic acid)	orange, lemon, tomatoes, milk.	Scurvy	75 mgm.
Vitamin D (Calciferol)	cod-liver oil, hali-but oil, milk, egg, liver.	Ricket, Dental caries, osteomalatia	400-800 I. U. in growing children
Vitamin E (Tochpherols)	egg, milk, fish, muscles, corn.	Sterility, Muscular Dystrophy.	15 to 20 mgm.
Vitamin K (Anti-Haemorrhagic factor)	cabbage, alfalfa, tomato etc.	Haemorrhages.	5 m gm. either orally or by injection.

Q. 14. Write Short Notes on :

(1) **Thiamine :** It is an anti-neuritic or anti-beriberi vitamin. *Sources* : Thimin is found in free from in liver, kidney, rice polishings, peanuts, peas and beans. *Properties* : (i) It is soluble in water, (ii) It can stand on cooking or boiling at 100°C for a short period. (iii) It withstands drying, picking or canning without loss of potency. (iv) In dried form, it stands heat better. (v) It is resistant to strong acids. *Functions* : (i) It is essential in carbohydrate metabolism. (ii) It aids in oxidative removal of pyruvic and lactic acids. (iii) It helps in cell-respiraion. (iv) It is synthesised by the intestinal bacteria in the intestines.

(2) **Thamine Deficiency :** The different types of sings and symptoms of thiamine deficiency are the following : (i) The normal growth in young individual has been arrested. (ii) There will be loss of appetite and tone of gastro-intestinal tract. (iii) The slowness of heart rate will occur. (iv) The lactic acid and pyruvic acid are accumulated in the blood. (v) There will be mental changes like depression, irritability, anxiety or fearfulness. (iv) There will be beri-beri which is characterised by enlargement of heart, inflammatory changes in the wall of stomach and duodenum, nystagmus of the eyeball, degeneration of the peripheral nerves, loss of deep reflexes, paralysis of the muscles and loss of appetite, nausea and vomiting.

(3) **Riboflavin** : It is a water-soluble vitamin found in the yeast, liver, kidney, milk, egg, meat etc. *Properties* : (i) Riboflavin crystallises from dilute acetic acid, alcohol in fine orange-yellow needles, (ii) It is a yellowish green pigment, slightly soluble in water and is insoluble in ether, chloroform and benzene. (iii) It is heat-stable, stands in ordinary cooking, canning but destroyed by light (iv) It produces a yellow solution having a yellow-green fluorescence. *Functions* : (i) It is essential for body growth. (ii) It is the prosthetic group of so many enzyme systems, (iii) It is one of the major component of yellow enzyme of Warburg and essential for tissue oxidation. (iv) It regulates the functions of some endocrine organs, particularly those which are connected with carbohydrate metabolism.

(4) **Cyanocobalamine (Vit. B_{12}) :** It is an anti-pernicious anæmic factor vitamin, isolated from liver by *Smith* and *Parker* in 1948. *Sources* : It is found in mammalian muscle, liver, kidney, pancreas, egg yolk, cheese etc. *Properties* : (i) It is a red cystalline substance and soluble in water. (i) It contains metalloporphyrin nucleus and cobalt. (iii) It is acidic of 4·5 ph. (iv) Its molecular weight becomes 1,500 appoximately. *Functions* : (i) It helps in the formation and maturation of red blood cells. (ii) It plays an essential role in the synthesis of

nucleic acid. (iii) It increases the white cell count in the bone-marrow. (iv) It is concerned with the maintenance of normal health of the body. (v) It helps in the transmethylation process.

(5) **Anti-Vitamin :** It is a substance which has got action interferring with the utilisation of a vitamin. *Types of actions :* (i) These substances have got structural and chemical groups similar to vitamins but do not play any part under normal physiological condition in the body, (ii) These substances destroy vitamins like the enzyme thiaminase that destroys thiamine. (iii) There are some chemical substances that make the vitamins ineffective like 'avidin' which it found in raw egg-white, binds and prevents the action of biotin.

(6) **Pangamic Acid (Vitamin B_{15}) :** Pangamic acid is a nitrogenous derivative of a complex ester of gluconic acid and acetic acid containing four methyl groups. *Source :* It is present in the seeds of many plants. It is also been isolated from the blood and liver of horse. *Functions :* (1) It heightens the utilization of oxygen by the cells and promotes the oxidation of alcohol in the organism. (2) This compound is used for the treatment of certain cardiac and vascular diseases.

(7) **Vitamin P :** It is water soluble permeability vitamin present in a group of plant pigments or flavonoids. *Source :* It is isolated from lemon rind (hesperidin), from buck wheat leaves (rutin) and from green leaves of the tea plant. *Function :* It lowers the premeability of the capillaries and has a therapeutic effect. *Deficiency signs :* The Vitamin P deficiency increases the permeabilily of the capillaries and makes their walls more fragile, leading to haemorrhages into the skin and other organs.

(8) **Biotin (Vitamin H) :** It is a water soluble vitamin and component of the active group of the enzymes that are concerned with the carboxylation of dicarboxylic and tricarboxylic acids. *Sources :* Biotin is present in all common articles of food specially in yeast, kidney, liver, cauliflower, peas, raw egg white containing avidin, etc. *Function :* (i) Biotin coenzymes are concerned with the carboxylation of dicarboxylic and tricarboxylic acids. (ii) It prevents dermatities in rats and dogs. *Deficiency signs :* The biotin deficiency causes dermatities in dogs and rats, distrubances of appetite, weakness and somnolence are encountered in man.

CHAPTER
SIX

BLOOD

Introduction: Blood is a highly complex fluid connective tissue of the body in which cellular elements like the red blood cells, the white blood cells and the platelets are suspended in the fluid plasma. The specific gravity of blood varies from 1055 to 1060. When blood is freshly shed, it is red, thick, opaque and slightly alkaline but afterwards it clots and serum separates out. It serves the function of transport of respiratory gases, nutrition, waste products, defensive function and maintenance of acid base equilibrium, blood pressure water balance and normal body temperature regulation, etc.

Q. 1. Describe the composition and functions of Blood.|

Blood is a connective tissue of the body in which solid elements like corpuscles or blood cells are suspended in the fluid plasma. It serves the function of transport of respiratory gases, nutrition, waste products and maintenance of acid base equilibrium, normal body temperature regulation and water balance, etc.

Physical Properties of Blood :

1. **Colour :** The colour of the blood varies. The arterial blood is bright red due to the presence of oxyhaemoglobin and the venous blood is dark red in colour due to the presence of reduced haemoglobin.

2. **Taste :** The taste of blood is somewhat salty due to the presence of inorganic salts,

3. **Odour :** Blood has a characteristic odour and that was due to the presence of volatile fatty acids.

4. **Temperature :** The temperature of freshly shed blood is 36°C to 38°C.

5. **Specific gravity :** The specific gravity of blood varies between individuals from 1055 to 1060. The specific gravity rapidly falls after birth due to destruction of red blood cells.

6. **Viscosity :** The viscosity of blood varies between 5 to 6 times than that of water. The viscosity rises in acidosis, hyperglycaemia and hypercalcaemia.

7. **Osmotic Pressure :** The osmotic pressure of plama is 25 m.m. of Hg. It regulates the interchange of fluids between the blood and tissue cells.

8. **Conductivity :** Blood is a good conductor of electricity. The conductivity varies according to the amount of inorganic salts present in the blood.

9. **Reaction :** Blood pH varies from 7·38 to 7·45 accordingly as the blood is venous or arterial.

Chemical Composition of Blood :

I. Cellular Elements (Formed Elements) ; 45%
   - (a) Red blood corpuscles or Erythrocytes or R.B.C,
   - (b) White blood corpuscles or Leucocytes or W.B.C.
   - (c) Platelets or Thrombocytes.

II. Plasma or Liquid portion : 55%
   - A. Water : 91 to 92%
   - B. Gases ; Nitrogen, Oxygen, Carbon dioxide, etc.
   - C. Solids : 8 to 9%
   - (a) Inorganic Constituents : 0·9%

     Sodium, Potassium, Calcium, Phosphorus, Megnesium, Sulphates, Phosphates, Iron, Iodine, Copper. Chlorides, Bicarbonate etc.
   - (b) Organic Constituents :
     - (1) Proteins : 7 to 8%

       Serum albumin, Serum globulin, Fibrinogen, Prothrombin etc.
     - (2) Non-Protein Nitrogenous substances (N.P.N) :

       Urea, uric acid, xanthine, hypoxanthine. creatine. creatinine, ammonia and aminoacids etc.
     - (3) Non-Protein Non-Nitrogenous substances :

       Neutral fats, phospholipids, cholesterol, glucose, cholesterides, etc.
     - (4) Other Organic constituents :

       Internal secretions, antibodies and various enzymes like amylases, proteoses, lipases, esterases, etc.
     - (5) Pigments :

       Bilirubin, Xanthophyllin, Carotene etc.
     - (6) Protective substances :

       Opsonins, Agglutinins, Precipitins, Complements, etc.

Functoins of Blood :

1. **Respiratory :** The transport of oxygen from the air in the lungs to the tissues and of carbon dioxide from the tissues to the lungs.

2. **Nutritive :** The nutritive constituents like glucose, amino-acids and fats are absorbed from the alimentary canal to the blood and are carried by the blood to the tissue cells for growth and energy.

3. **Excretory :** Blood is the medium through which various waste products like urea, uric acid, creatinine etc, are eliminated from the body by the excretory organs like kidney, skin etc,

4. **Vehicle :** Blood acts as a medium through which hormones, vitamins and other essential chemicals are carried to the different tissues of the body.

5. **Water Balance regulation :** Blood maintains the normal water contents of the tissue.

6. **Body temperature regulation :** The constant circulation serves to maintain the uniform temperature at the different parts of the body.

7. **Acid-base regulation :** With the help of Kidney, Skin and Lungs, Blood helps to maintain a constant reaction of the body.

8. **Defensive mechanism :** The blood and lymph contain certain chemical substances of complex nature like antitoxins, lysins, antibodies etc. which save us from bacterial infection. The white blood cells by their phagocytic properties engulf bacteria and foreign particles.

9. **Coagulation of blood :** After the blood has been shed a clot is formed at the seat of injuries and guards against haemorrhage.

10. **Osmotic Pressure ;** Blood maintains a steady osmotic pressure in the tissues and fluids of the body assisted by kidneys and skin.

11. **Blood Pressure regulation :** The blood pressure is regulated by changing volume and viscosity of blood.

Q. 2. What is the Specific Gravity of Blood ? How it is determined ?

The specific gravity of human blood becomes 1055 to 1066 taking specific gravity of water is 1000. Though it is constant, it varies according to intake of fluid or output of fluid through sweat or urine. The specific gravity of fœtal blood in full term is higher than that of mother at that time. The specific gravity rapidly falls after birth due to destruction of red blood cells.

Specific gravity of Blood Rises : The specific gravity of blood rises due to :

(1) When water is lost from the body such as excessive Sweating, Cholera, Diarrhoea etc.

(2) By exudation of fluid into tissue or serous cavities due to inflammation, surgical operation or burns.

(3) When water intake is inadequate.

Specific gravity of Blood Falls : The specific gravity of blood falls due to :

(1) When large amount of water is taken.

(2) Injection of saline into veins causing dilution of blood.

(3) In severe haemorrhage after which fluid is drawn in from tissue-space and the blood is diluted.

Determination of Specific Gravity of Blood :

Principle : The principle adopted is to add drops of blood to a series of solution of known specific gravity and to note in which particular solution of blood drop neither sinks nor floats. The specific gravity of that particular solution indicates the specific gravity of blood sample.

Hammerschlag's Method : In this method, the drop is placed in a mixture of chloroform and benzene (Specific gravity of chloroform is 1066 and of Benzene below 1000). The mixture was made in such a way that specific gravity of it is about to say 1055. Then it is taken in a cylinder and in it a drop of blood is placed. In the mixture, the drop will either sink or float or will neither sinks nor floats. If it remains in any position, the specific gravity of blood will be same as that of the mixture. When it sinks, add more benzene until the drop remains in any position whatsoever. Then the specefic gravity of the mixture will be determined in the normal way. Now-a-days, a solution of Copper sulphate of different strength is used which are kept in different cylinders.

Q. 3, What is the Reaction of Blood or Blood pH ? Describe the different factors which maintain the pH of blood.

Blood is a body fluid which is alkaline towards litmus. It contains H-ions but they are over balanced by OH-ions. The principal acid to which this Hydrogen ions concentration is due to carbonic acid and if carbonic acid gas is passed into water or a physiological saline solution in increasing amount, the concentration of H-ions increases also. Carbonic acid is continually being thrust into the blood by the tissue and the reaction is but little disturbed because of the mechanism which exists for its transport. The maintenance of the acid base equilibrium of the blood is very important.

The blood pH varies from 7·38 to 7·45 according as the blood is venous or arterial. The venous blood and arterial blood are alkaline but venous blood is less alkaline in reaction because it contains more carbonic acid.

Factors maintaining the pH of Blood : There are different factors that maintain the pH of the blood which are the following :

I. **Blood Buffers** : The blood buffers are the sodium bicarbonate, disodium hydrogen phosphate, plasma protein as sodium proteinate and potassium haemoglobinate.

The **protein buffers** of blood plasma such as albumin and globulin are probably of greatest importance in the blood. The plasma proteins remain mostly combined with sodium ion and help in buffer systems as *sodium proteinate* and *carbamino compound* formation.

The **red blood cells buffers** are the presence of large amounts of the protein haemoglobin. **Haemoglobin** is an important protein buffer found in red blood cells and is very efficient to deal with carbonic acid. It is known how the "chloride shift," carbon dioxide from the tissues diffuses into the red blood corpuscles and is converted into carbonic acid by carbonic anhydrase which is buffered at once by potassium-haemoglobin.

II. **Kidney** : The kidney maintains the normal reaction of blood by the following ways :

(*a*) *By directly eliminating Acids and Alkalies* : The lactic acid reacts with the buffer sodium proteinate forms sodium lactate and reduced protein.

(*b*) *By Ammonia Mechanism* : Ammonia mechanism of kidney also prevents acidity of blood. Where there is excess of acid kidney forms ammonia from amino-acid. Alanine is hydrolysed into ammonia and propionic acid in the kidney by the enzyme. This ammonia thus liberated is utilised for the neutralisation of the acid that may remain in the blood stream.

(*c*) *By preserving the Alkali Reserve of Blood* : Sodium bicarbonate is the chief alkali reservoir of blood and available for neutralisation of acid. The diminution of alkali reserve of blood is known as Acidaemia. In acidosis, reaction of blood does not become acid, but the reserve of alkali becomes less. Increase in alkali reserve is known as alkalimia. The **acidosis** may occur due to : (i) By taking certain drugs such as ammonium chloride. It decomposes into ammonia and hydrochloric acid and ammonia escapes through and hydrochloric acid diminishes the alkali reserves. (ii) During muscular activity, large amount of CO_2 and lactic acid is produced. (iii) In diabetes mellitus, certain acids e.g. β-hydroxy butyric acid, Aceto-acetic acid are produced and appear in the blood. (iv) During starvation. (v) Taking of excessive protein product as they contain sulphur and phosphorus and thereby sulphuric acid and phosphoric acids are produced. The **alkalosis** may be produced due to : (i) When ammonium bicarbonate is taken as a drug. (ii) The vegetable food stuffs as they contain citrates and tartrate and carbonates and CO_2 enters the blood stream and thereby increases the alkalinity. (iii) In voluntary deep breathing known as hyperpnoea, as in it, acid is liberated in large quantities.

III. **Lungs** : In the lungs the more acidic oxyhaemoglobin tends to force the reaction in the opposite direction. CO_2 diffuses from the red blood corpuscles to the plasma and then to the alveolar air. Whenever there is excess accumulation of carbonic acid in the blood, there will be stimulation of respiratory centre and large amount of CO_2 will be evolved out through the expired air to maintain the normal pH of the blood.

During acidosis, the respiratory centre is stimulated, pulmonary ventilation is increased, and more of the CO_2 is eliminated. During alkalosis the respiratory centre is depressed, pulmonary ventilation diminished and CO_2 is retained.

IV. Skin. Carbonic acid may be liberated out through the sweat to maintain the normal pH of the blood, The sweat excretes acids during acidosis and alkalies during alkalosis.

Q. 4. Describe the origin (Development), fate and functions of Erythrocytes or Red blood cells.

Blood is a connective tissue comprising 55% liquid plasma and 45% cellular elements. The red blood cell is one of the contituents of the cellular elements of blood that possesses the phenomenon of birth, continuity of life and death.

Development (origin) of Red Blood Cells : The red blood cells originate and mature in the human body by the following mechanisms ;

I. Site of Development :

(a) Pre-natal development (Origin before birth) :

1. *In third week of foetal life* (*Mesoblastic Stage*) : In this stage of development of R. B. C, and blood vessels take place in the early embryo. In the mesoderm of the wall of the yolk sac, there is a particular area called 'area vasculosa' and first at that part the development begins, As the development proceeds a fluid appears inside the cell. The interconnecting cells of blood plasma inside, forms a system of primitive blood vessels and found lined by a single layer of flat nucleated cell known as endothelial cells, from which red blood cells develop.

2. *After third month of foetal life* : In this stage, the spleen and especially the liver are the most important sites of intravascular blood formation.

3. *About the middle of foetal life* (*Hepatic Stage*) : In this stage. the nucleated red cells disappear completely from the blood. The bone marrow begins to act as a blood forming organ because it is normally the sole region where the red cells are formed after birth. This lack of oxygen stimulates the multiplications of the endothelial cells and large number of R. B. C. are formed.

(b) Post-natal development or **Myeloid Stage** : (Origin after birth) : The bone marrow is the main site of erythrogenesis, At first all the bones are filled throughout their length with red marrow. At the age of twenty, all marrow of long bones is yellow and R. B. C. formation is stopped. In the adult, red marrow persists mainly in the vertebrae, sternum, ribs and bones of the skull and continue to form R. B. C. throughout the life.

II. Theories of Origin : Regarding the origin of red blood cells there is a good deal of controversy. A number of theories came forward to establish the red cell formation but none of them come into final conclusion.

(a) **Monophyletic Theory :** According to this theory both R.B.C. and W. B. C. are originated from a single cell situated outside the vessels known as haemocytoblast,

(b) **Dualistic Theory :** The formation of R. B. C. is an intravascular process develop from the endothelial cells lining the vessels.

(c) **Trialistic Theory :** Monocytes are quite separate from the myeloid elements that develop from reticulo-endothelial cells.

(d) **Polyphyletic Theory :** Different types of cellular elements of blood develop from different saurces. R. B. C. are developed intravascularly.

III. Stages of Development :

Endothelial cell : It is formed from the haemocytoblast possessing :

(Haemocytoblast)

(1) Big cell, 18-23 μ diameter, with a large nucleus and a thin rim of basophilic cytoplasm.

(2) Large, undifferentiated R. E. cells, lining the sinusoids of bone-marrow.

↓

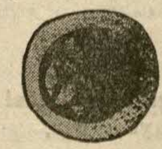
Megaloblast cell : It is directly formed from the endothelial cells possessing :

(Proerythrobast)

(1) Large vascular nuelcus with well marked nucleous.

(2) Proesence of scanty chromatin.

(3) Detection ofhaemoglobin in fresh preparations.



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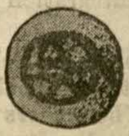
Early Erythroblast cell : It is the largest cell of the erythroid cells develops from megaloblast cell with the help of *Castle's haematinic principle*, possessing :

(Early Normoblast)

(1) The nucleus is large relative to the amount of cytoplasm.

(2) Presence of fine chromatin network.



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Late Erythroblast cell (Intermediate normoblast) : The early erythroblast cell divides by mitosis to give rise to smaller late erythroblast cell by the activation of *folic acid* and *Vitamin* B_{12} and possessing :

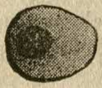
(1) An eccentric nucleus.

(2) Dense chromatin network.

(3) Few mitochondria and more haemoglobin.

↓

Normoblast cell (Late Normoblat) : This cell develops from Late erythroblast cell by the activation of *Vitamins like Vit. C, Vit.* B_2 and *Nicotinic acid* and *Minearls like Iron, Copper, Cobalt* and *Magnesium.* This cell possesses : (1) Nucleus stains deeply with basic dyes. (2) Absence of chromatin network (pyknosis). (3) Nucleus soon disappears, (4) Haemoglobin content attains its maximum level.



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Reticulocyte cell : This cell develops from normoblast cell by loosing their nuclei, possessing ; (1) A network of reticulum is apparent in the form of a clumps of small dots, or as a faint thread. (2) The reticulum is probably a precipitate of remnants of the basophil cytoplasm of the immature cell.

↓

Normal Erythrocyte cell : It is a normal red cell which develops from reticulocytes with the help of *Thyroxine* possessing : (1) Disappearance of reticulum. (2) Remnant of reticulum forms into haemoglobin. (3) The cell is circular, non-nucleated biconcave disc, markedly elastic.

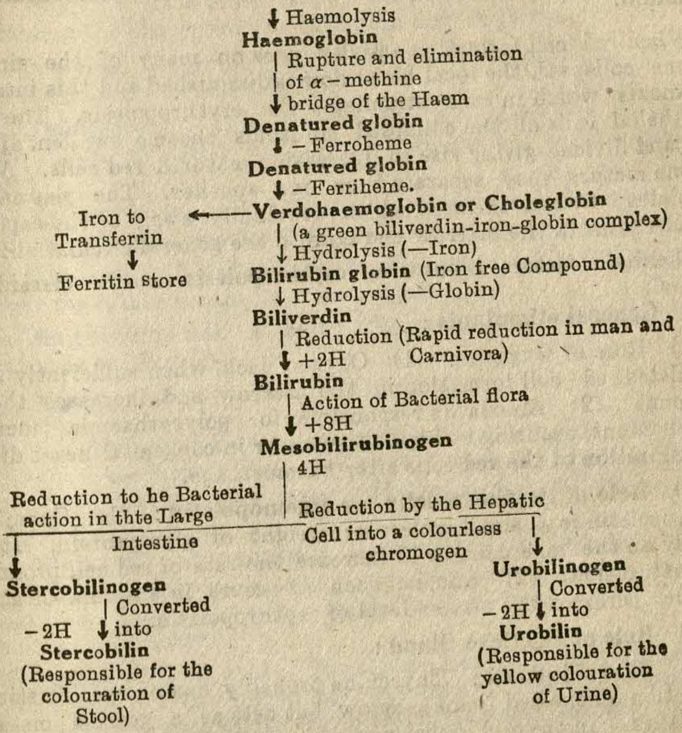
Fate or Degradation of Red Blood Cell :

The red blood cells are destroyed either by natural accidental condition or during stage of senility after attaining 120 days of age,

I. Natural death : There are following possible ways by means of which red cells normally might be destroyed : (1) By the macrophages of the spleen. (2) By the action of haemolylic substance in the blood such as hydrochloric acid, water and concentrated solution of plasma. (3) Through simple wear and tear and disintegration in the blood stream.

II. Senile death : After a life span of some 120 days the red cells are destroyed, being phagocytosed by macrophages of the reticulo-endothelial system in the spleen, liver and bone marrow. The process of break-down of haemoglobin formed from the red blood cells due to haemolysis is as follows :

RED BLOOD CELLS


Haemolysis
Haemoglobin
Rupture and elimination of α – methine bridge of the Haem
Denatured globin
– Ferroheme
Denatured globin
– Ferriheme.
Verdohaemoglobin or Choleglobin
(a green biliverdin-iron-globin complex)
Iron to Transferrin
Ferritin store
Hydrolysis (—Iron)
Bilirubin globin (Iron free Compound)
Hydrolysis (—Globin)
Biliverdin
Reduction (Rapid reduction in man and Carnivora)
+2H
Bilirubin
Action of Bacterial flora
+8H
Mesobilirubinogen
4H
Reduction to he Bacterial action in thte Large Intestine
Reduction by the Hepatic Cell into a colourless chromogen
Stercobilinogen
Converted into
–2H
Stercobilin
(Responsible for the colouration of Stool)
Urobilinogen
Converted into
–2H
Urobilin
(Responsible for the yellow colouration of Urine)

Functions of Red Blood Cells :

(a) **Respiratory functions :** Haemoglobin present in the red blood cells acts as a carrier of oxygen from the lung to the tissue and it also acts as carrier of carbon dioxide from the tissue in the blood.

(b) **Buffer action :** Haemoglobin present in the red blood cells acts as a buffer action in the blood.

(c) **Reaction of Blood Regulation :** Haemogiobin in the red blood cells is responsible for the regulation of the normal reaction of blood.

(d) **Maintenance of ionic balance :** Red cells maintains ionic balance by its possesssion of its permeability character.

(e) **Carrier of Nutrients :** Red blood cells receive the nutrients like iron and is carried to the cell.

(f) **Maintenance of Viscosity of Blood :** Red blood cell is responsible for the maintenance of the viscosity of blood.

(g) **Formation of Various Pigments :** Various pigments like bilirubin, biliverdin etc. are derived from haemoglobin after the disintegration of red blood cells.

Q. 5. Describe how Erythropoiesis (Red cell development) is regulated.

When red cell formation activity goes on many of the sinusoids become collapsed, the local blood flow is diminished and this intensifies the anoxia which in turn stimulates the erythropoiesis. The living endothelial cells of the collapsed sinusoids become swollen, differentiate and divide, giving rise to increasing matured red cells. As they become mature, they separate from one another. The plasma then percolates between the cells which are finally swept of the capillaries into the veins of the marrow and go into the general circulation.

The main factors influencing erythropoiesis can be classified as follows :

I. General stimulants :

(a) **Role of Oxygen :** (1) Oxygen lack, when sufficiently severe stimulates red cell formation in the marrow and increases the red cell count. (2) Anoxia is responsible for polycythaemia (increased red cell count) occuring at high altitudes or in congenital heart disease. for restoration of the red cells after haemorrhage.

(b) **Role of Erythropoietin or Haemopoietin :** (1) Chemically, erythropoietin is a small molecular weight of glycoprotein. It acts directly on the bone marrow to increase the rate of red cell production and maturation. (2) Anoxia, such as occurs in anaemia or at high altitude, increases the plasma level of erythropoietin.

(c) **Role of Ductless Gland :**

(1) **Thyroid gland :** Thyroxine probably has no specific stimulating action on the red bone marrow but acts as a general metabolic stimulants. In thyroid deficiency i.e., in *myxoedema* and *cretenism*, macrocytic and hypochromic type of anaemia commonly occurs.

(2) **Pituitary Gland :** In disorders of pituitary, distrurbtnces of blood formation occur and thus anaemia is common is Simmonds' disease.

(3) **Supra-renal Cortex ;** Polycythaemia may occur in *Cushing's syndrome* due to hypersecretion of adrenocorticotropic hormone or overaction of the adrenal cortex.

(d) **Role of Vitamins :**

(1) **Vitamin C ;** It is uncertain if Vitamin C lack alone can cause anaemia which may be due to associated dietary deficiencies including lack of Iron.

(2) **Vitamin D and G :** Similar general dietary deficiencies are probably the causes of anaemia associated with *rickets* and *pellagera*.

II. Factors affecting haemoglobin formation ;

(a) **Iron ;** It helps for the synthesis of haem when reduce ferric iron combines with porphobilinogen or protoporphyrin IX, it forms haem.

(b) **Copper :** It is essential for haemoglobin synthesis, probably by promoting the absorption, mobilization and utilization of iron.

(c) **Proteins :** A protein intake retards haemoglobin regeneration even in the presence of excess iron.

(d) **Amino-acids :** It is essential for the formation of globin. and the usual essential amino-acids are needed for haemoglobin formation.

(e) **Hydrochloric acid :** Presence of hydrochloric acid in the stomach helps in the formation of *Castle's haematinic principle.*

(f) **Bile salts :** They help in the absorption of iron and copper that serve for futher synthetis of haemoglobin.

(g) **Magnesium and Cobalt :** These are the also necessary for the synthesis of haemoglobin.

III. Maturation factors :

(a) **Endothelial cell to Pro-erythroblast stage :** Nothing is known about the factors concerned in this stage of red cell formation. Arrested development at the stage of the endothelial cell leads to aplastic anaemia.

(b) **Maturation of nucleated erythroblasts :** For this stage of development special maturating principles are necessary such as Vitamin B_{12}, Folic acid, minerals like cabalt, iron, copper etc. and Castle's intrinsic factor.

(1) **Action of Folic acid :** It plays an important part in a number of bio-chemical actions including methylation, transmethylation and the synthesis of nucleic acids. Folic acids induces maturation of megaloblasts to normoblasts.

(2) **Action of Vitamin B_{12} :** It plays an important role in a number of bio-chemical actions and the synthesis of nucleic acid and maturation of megaloblasts to normoblasts stage. Administration of Vitamin B_{12} will relieve pernicious anaemia.

(3) **Actions of Castle's Haematinic principle :** Castle originally suggested that an "extrinsic factor" present in food or Vitamin B_{12} interacted with "intrinsic factor" secreted by the stomach to form "haematinic principle" which was stored in the liver.

(4) **Action of Cobalt :** Large dose of cobalt produce polycythea-mia, perhaps by increasing the production of erythropoietin.

Q. 6. What is Castle's Haematinic Principle ? Describe the mode of action and Fate of haematinic principle.

The *Extrinsic factor* is present in rice polishing, meat, yeast cells and yeast extracts, Vitamin B_{12}. The *Intrinsic factor* is an enzyme present in the gastric juice and is secreted by the cells of the fundus of the stomach. The extrinsic factor modifies it or interacts with it so as to promote its absorption from the intestine.

Mode of Action ; The haematinic principle promotes maturation of erythroid cells and enables them to follow the normal line of development as regards the cell size and the time of appearance of heamoglobin. At the red cells complete their maturation, young reticulocytes begin to appear in the circulation and subsqently there will be rise of red cell count.

Fate of Haematinic Principle : The haematinic principle is formed in the stomach and passes into the small intestine. Then it is absorbed into the portal blood and ultimately reaches into the liver where it is stored. It passes from the liver to the bone marrow by the blood stream and helps in the conversion of megaloblast into erythroblast stage.

Q. 7. How do you estimate the number of R.B.C. and W.B.C. in the blood ?

The total number of red blood cells and the total and differential count of white blood cells per cu. m.m. of blood are estimated with the help of an instrument known as *Thoma-Zeiss Haemocytometer*.

Principle ; In order to enumerate the corpuscles a known volume of blood is diluted with a known amount of diluent and the number of cells in a measured volume of the mixture is counted with a haemycytometer.

Description of the Apparatus :

I. **Instruments Required** : The Thoma-Zeiss Haemocytometer consists of thick glass Counting Chamber, Red and White cell diluting pipette and Cover glass.

A. **Counting Chamber** : Numerous types of counting chambers with various types of markings have been designed. The type which is widely used at the present time is discussed here.

This haemocytometer consisting of double counting chamber is a heavy thick glass slide usually at the centre with three platforms separated by widegrooves. The central platform is lower than its neighbour and if a cover glass is placed on them, there is a depth of $\frac{1}{10}$ m.m. The whole square of the counting chamber is divided into 16 big squares, each big squares is subdivided into 16 small squares, the cubic capacity of each small square being $(\frac{1}{20} \times \frac{1}{20} \times \frac{1}{10}$ c.m.m.$)$ or, $\frac{1}{4000}$ c.m.m.

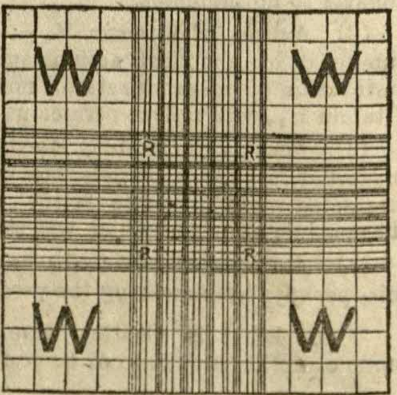


Fig. 2. Countig Chamber.

B. **Red and White Cell Diluting Pipette.** (Graduated Blood Drawing Pipettes): For diluting blood and other fluids the Thoma type of glass pipette is most widely used. The haemocytometer pipette consists of a graduated capillary tube with an engraved mark and a mixing bulb which contains a glass bead, to facilitate the mixing. The pipette is provided with marking as follows :

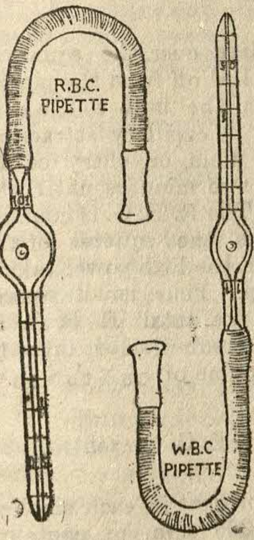


Fig. 3. Diluting Pipettes.

(a) R. B. C. pipette usually has a red glass bead inside the bulb having marks 0·5, 1, 101, the total capacity of the bulb is 100 or 200 and the actual dilution is 0·5 to 100 or 1 to 200.

(b) W. B. C. pipette containing usually a white glass bead in the bulb, having marks 0·5, 1, 11, the total capacity being 10 or 20.

C. **Cover Glass**: It is a very thick specially designed rectangular polished cover-glass, ground perfectly plane which just covers the groove portion of the counting chamber.

II. Diluting Fluids or Diluents: The most commonly used diluting fluids for white and red blood cells are ;

(A) **R. B. C. Fluids**; The different types of R. B. C. fluids are as follows :

(a) *Hayem's Fluid*: It is made up of ; (i) Mercuric Chloride—0·5 gm, (ii) Sodium chloride—1 gm. (iii) Sodium Sulphate—5 gm. (iv) Distilled water—200 ml.

(b) *Toisson's Fluid*: It is made up of ; (i) Methyl Violet—0·25 gm. (ii) Sodium Chloride—1 gm. (iii) Sodium Sulphate—8 gm. (iv) Neutral Glycerine—30 ml. (v) Distilled water—160 ml.

(B) **W. B. C. Fluids**: The W. B. C. fluid contains ; (i) Glacial acetic acid—2 ml. (ii) Gentian violet solution (1% aqueous)-- 1 ml. (iii) Distilled water—100 ml.

Procedure For Counting ;

A. **Collection of Blood** (Filling and Shaking); The finger is aseptically puntured, so that blood flows on' freely. The first drop is discarded, then the blood is sucked up in the R. B. C. and W. B. C. pipette respectively up to the mark 0·5 or 1. Immediately, the blood is diluted with diluting fluid upto the mark 101 incase of R. B. C. count ; upto the mark 11 in case of W. B. C. count. The pipettes are rolled rapidly between the palm, so that the corpuscles are evenly distributed. Care must be taken of that no air bubbles can pass either in the stem or in the bulb.

B. Process of Counting and Calculation ;

I. In Red Blood Cell :

Counting ; Put clean grease free cover glass over the square of the counting chamber. The clear fluid is expelled off from the pipette and then a drop of the mixture is ejected from the bulb to the edge of the coverglass under which it is drawn by capillary attraction. Care should be taken to avoid overflow of the fluid or entry of air bubbles. Let the preparation stand for one or two minutes until the cells on to the bottom of the counting chamber. The R. B. C. is counted in the central big squares as follows ; Focus the squares of the counting chamber with low power and then with the high power taking care that you do not press over the coverslip. Four small square at the corner and a small square in the centre i.e. total R. B. C. in five squares are counted, Each small square is sub-divided into 16 smaller squares. Each smaller square has volume of $\frac{1}{10} \times \frac{1}{20} \times \frac{1}{20} = \frac{1}{4000}$ c.m.m.

Experimental Result : The number of R. B. C. present in 80 smaller squares are nearly about 450.

Calculation : Let the number of R.B.C. present in each smaller square contains $x/80$ R.B.C. Therefore 1/4000 c. m. m. contains $x/80 \times 4000 \times$ dilution of R.B C. (200 times). If the blood is drawn upto 0·5 ml. then number of R.B.C $= x/80 \times 4000 \times 200$ per c.m.m.

$\therefore$ R.B.C. persent per cu. m.m. of blood $= 450/80 \times 4000 \times 200 = 4·5$ million.

II. In White Blood Cell :

Counting : The clear fluid is expelled from the stem of W. B. C. pipette and a drop of the mixture is ejected as in case of R.B.C. The number of W.B.C. present in the big corner squares is counted.

Experimental Result : The number of W.B.C present in 4 big corner aquares are nearly about 80.

Calculation : Let W.B.C, present in 4 big squares is y. Therefore in one corner square, W.B.C. present $= y/4$. Each corner square has volume of 1/10 c.m.m. If the blood is drawn upto 0·5 ml., then number of W.B.C. $= y/4 \times 10 \times$ dilution of the solution 20 times.

$\therefore$ W.B.C. present per c.m.m. of blood $= 80/4 \times 10 \times 20 = 4000$,

Q. 8. Describe the varieties, chemistry, properties, synthesis and bio-synthesis of Haemoglobin.

Haemoglobin, the respiratory proteins of vertebrate erythrocytes is a conjugated protein or chromoprotein prerent in the red blood cells. It consists of basic protein globin (histone) united with four prosthetic haem groups. Haemoglobin is the red pigment which gives blood its characteristic colour.

Varieties or Different types of Haemoglobins :

I. **Physiological Haemoglobins :** There are at least three types of human haemoglobin, the haem moiety is the same, physical and the chemical differences being due to variations in the globin fraction.

(a) **Foetal haemoglobin (HbF) :** It comprises the foetal series F having polypeptide chain and discovered by Hunt in 1959. It differs from adult haemoglobin only in the globin moiety but this has profound effect on the oxygen dissociation curve.

(b) **Adult haemoglobins (HbA) :** They comprise of adult haemoglobin series known as A, S, X, C, D, E, G, H, I, J, M, etc, discovered by Hunt, Ingram, Benzers, Jone in 1959. The globin of each of the forms of haemoglobin consists of four polypeptide chains, usually consisting of two each of two different kinds.

(c) **Minor Components :** These are haemoglobin A_2, G_2 etc.

II. **Pathological Haemoglobins :** Haemoglobin S is associated with sickle cell anaemia, when it is reduced it becomes much less soluble, the molecules become aligned and its haemoglobin contents undergoing tactoid change.

Chemistry of Haemoglobin : Haemoglobin is a conjugated protein in which four prosthetic haem groups are linked to a basic protein globin. The haem part of haemoglobin is a type IX ferro-protoporphyrin.

(a) **The Prosthetic group :** Porphyrins are large, flat, heterocyclic ring structures made up of four pyrrol rings linked together by methine($-CH=$) bridges. The four pyrrol rings carry two side chains each in the porphyrins, at positions numbered 1 to 8.

(b) **Globin :** It is made up of four polypeptide chains, two α-and two β-chains, both types having valine as the N-terminal amino-acids. The N-terminal amino-acid sequence of the α-chains is valine-leucine, and that of the β-chains is valine-histidine-leucine.

Properties of Haemoglobin :

(1) **Molecular weight :** The molecular weight of haemoglobin is about 68,000.

(2) **Chemical formula :** The approximate chemical formula of haemoglobin is $(C_{712}H_{1130}O_{245}N_{214}S_2Fe)_4$.

(3) **Action of Acids and Alkalies :** They act upon haemoglobin to separate haem from globin. Alkalies split haemoglobin and ferroheme, the latter then being oxidised to ferriheme, which is combined with hydroxyl ion to give alkali haematin.

(4) **Crystallisation :** Haemoglobin can be easily crystallised. The human blood forms rhombic prisms or needles.

(5) **Hydrogen-ion-concentrations :** The ph of haemoglobin is 6·8 and ph of oxyhaemoglobin is 6·6.

(6) **Spectroscopie appearance :** Reduced hemoglobin gives one broad band between the Fraunhofer's line D and E. The oxyhaemoglobin consists of two bands between D and E. The band nearer D is called α-band. The nearer E is broader and is called the β-band,

Synthesis of Haemoglobin : The synthesis done by the following steps : (1) Condensation of glycine with succinate, (2) Condensation of two molecules of δ-amino laevulic acid to form porphobilinogen. (3) Conversion of porphobilinogen into uroporphyrin. (4) Conversion of uroporphyrinogen to coproporphyrin, (5) Conversion of coproporphyrinogen to protoporphyrin. (6) Incorporation of Fe^{++} into protoporphyrin to from heme.

Bio-Synthesis of Haemoglobin :

(a) **Bio-Synthesis of Haem :**

(1) **Formation of porphobilinogn :** The condensation of active succinate (succinyl-coenzyme A) with glycine to give α-amino-β-ketoadipic acid. This is decarboxylated to δ-amine leavulic acid, two molecules of which combine with the elimination of water, to give porphobilinogen. Four molecules of porphobilinogen combine with reduced ferric iron and form haem.

(2) **Formation of Ferric Iron :** Iron is absorbed from the gut and forms ferritin in the mucosa in the ferrous state as transferritin stores primarily in the liver. Iron also occurs as ferritin in the bone marrow reticulum cells and transferred by pinocytosis to the erythroblasts.

(b) **Bio-Synthesis of Globin :** Experiments on dogs by lebelling the globin of haemoglobin with C^{14} lysine show that the globin has the same life span as the haem moiety of hoemoglobin. There is no evidence of preferential reutilization of globin in the bio-synthesis of new haemoglobin. It was shown that the globin derived from broken down red blood cells could not be re-utilized for fresh haemoglobin synthesis.

Q. 9. Describe the compounds, derivatives. formation, fate and functions of Haemoglobin.

Haemoglobin, the respiratory proteins of vertebrate erythrocytes, is a conjugated protein or chromoprotein present in the red blood cells. It sonsists of basic protein globin (histone) united with four prosthetic heam groups. Haemoglobin is the red pigment which gives blood its characteristic colour.

Compounds of Haemoglobin : (Addition Compounds).

There are two types of compounds of haemoglobin known as stable and unstable compounds.

(a) **Stable Compounds :**

1. **Carboxy haemoglobin :** When haemoglobin combines with carbon monoxide. Carboxy haemoglobin is formed. It contains

one molecule of corbon monoxide per iron atom. It is pink in colour with two sharp absorptiou bands in the green part of the spectrum. It is formed in the body when coal gas is inhaled or accidentally amongst miners in mine explosions and in closed room with fire and gas.

2. **Nitric oxide haemoglobin :** It is prepared by hydrolying blood with acid or alkali and passing nitric oxide gas. It is more stable than carboxy haemoglobin. This is formed in the blood when we inhale the fumes of bursting of a bomb.

3. **Nitroxy haemoglobin :** When haemoglobin combines with nitrous oxide, nitroxy haemoglobin is formed.

(b) **Unstable Compounds :**

1. **Carbohaemoglobin :** Carbon dioxide formed in the tissues combines with hemogolobin, an unstable compound known as carbohaemoglobin.

2. **Sulph-haemoglobin :** The sulfurated hydrogen (H_2S) is formed in the intestine specially in large intestine by the action of the bacteria over sulphur-containg acids. H_2S gets absorbed into the blood from intestine and forms sulph-haemoglobin.

3. **Oxyhaemoglobin :** It is formed when oxygen combines with haemoglobin. It is bright red in colour with two sharp absorption bands in the green part of the specturm.

Derivatives of Haemoglobin (Decomposition Compounds) :

(a) **Iron containing derivatives :**

1. **Haematin :** It is an oxidised haem. It contains acid haematin and alkali haematin.

2. **Haemochromogen** (Reduced alkaline haematin) : It is a compound formed by the combination of reduced alkaline haematin with denatured globin.

3. **Haemin** (Hydrochloride of Haem) : It is an artificial derivative of oxyhaemoglobin. It is of great importance and used in medicolegal work. Haemin crystals may be prepared by heating a little of the dry blood scarpings with glacial acetic acid and few crystals of sodium chloride, on cooling haematin crystals separate out.

4. **Cytochromogen or Cytochrome :** It is a mixture of several types of haemochromogen, Cytochrome is found in all animal and vegetable tissues.

5. **Methaemoglobin :** It is produced by the spontaneous oxidation of the ferrous iron of haemoglobin to the ferric state. It is brown in colour with four absorption bands in the visible spectrum.

6. **Haem:** It is a ferrous compound produced by the reduction of haematin in alkaline solution.

7. **Cathaemoglobin:** It is a compound of haem containing feric iron with denatured globin.

8. **Cyanmethaemoglobin:** It is bright red in colour. It is very stable compound and is easily formed by treating haemoglobin.

(b) **Iron-free derivetives:**

1. **Haematoporphyrin:** It is prepared by the haemoglobin or haemin with strong sulphuric acid. Is has got two types known as acidic and alkaline haematoporphyrin.

2. **Haemopyrrole:** When haematoporphyrin is reduced, haemopyrrol is formed. It is probably a mixture of several pyrrol compounds.

3. **Haematoidin:** It is a pigment of bile It is bluish green crystalline compound formed when biliverdin is oxidised.

4. **Bilirubin:** It is a pigment of bile. It is bluish green crystalline compound formed when biliverdin is oxidised.

5. **Urobilin:** It is formed from the bile pigments produced by the reduction of the hepatic cells.

6. **Stercobilin:** It is a brown pigment and reduction product which is derived from the bile pigment by the bacterial action in the large intestine. It gives the normal colour of the stool.

Formation of Haemoglobin: The haemoglobin is probably formed in the tissues which manufacture R.B.C. that contains it. The articles of diet made from blood are of no value as sources of iron to body. The exact source of pyrrol remains unknown but the globin is probably synthesised.

Factors necessary for Haemoglobin formation: There are a number of factors necessary for haemoglobin formation. They are: (1) Raw materials must be available in adequate amount namely iron and porphyrins for haem and proteins for globin. (2) Copper is also needed. (3) HCl of the gastric juice liberates food iron in inorganic from. (4) Bile salts facilitate absorption.

Fate of Haemoglobin (Degradation of Haemoglobin):

After a life span of some 120 days, the red cells are destroyed being phagocytosed by macrophages of the reticulo-endotheial system in the spleen, liver and bone-marrow. The breakdown of haemoglobin starts by rupture of the α-methine bridge of the haem, the α-carbon being elimimated to give a green biliverdin-iron-globin complex, known as verdohaemoglobin or choleglobin. Iron is removed and attached to transferrin to transport to sites of storage as ferritin, globin is liberated and enters the general pool of protein metabolism, while the biliverdin is reduced to bilirubin. Bilirubin forms mesobilirubinogen by the action of bacterial flora which forms stercobilinogen and urobilinogen by the bacterial action and reduction by hepatic cells respectively. Stercobilinogen is partly reasorbed into the plasma and excreted by the kidney into the urine or by the liver into the bile.

Functions of Haemoglobin :

(1) **Respiratory :** Haemoglobin is essential for carriage of oxygen from the lungs to the tissues and transport of carbon dioxide from the tissue to the lungs.

(2) **Buffer action :** Haemoglobin acts as a buffer which helps in the regulation of blood reaction.

(3) **Viscosity of Blood :** Haemoglobin after dissolving in plasma would increase its viscosity due to its inclusions in the corpuscles.

(4) **Osmotic pressure :** It raises its osmotic pressure by about 100 m. m. of mercury and so entirely derange the mechanism of water interchange between the capillaries and inter tissues spaces.

(5) **Formation of various pigments :** Haemoglobin is responsible for the formation of different types of bile pigments like bilirubin, biliverdin, stercobilin and urobilin etc.

(6) **Regulation of Blood Volume :** The haemoglobin is dissolved in plasma which increases the viscosity and raises the osmotic pressure by about 100 m.m. Hg. and so would have entirely deranged the mechanism of water interchange between the capillaries and tissue spaces.

(7) **Regulation of Blood reaction :** The haemoglobin is responsible for the regulation and maintenance of the normal reaction and acid-base balance of blood.

Q. 10. What are the different methods of examination of Haemoglobin ? Describe one of the method of estimation of Haemoglobin.

The haemoglobin is a conjugated chromoprotein present in the red blood cells. During haemolysis, haemoglobin is coming out from the red blood cells.

Different Methods of :Estimation of Haemoglobin : There are a number of methods by means of which haemoglobin is estimated which are as follows :

(a) **Tall Quist Chart :** The patient's blood is soaked in a trace of filter paper and compared against a standard column scale before the blood dries up. It is not an accurate method.

(b) **Haldane's Haemoglobinometer :** Blood is haemolysed, saturated with carbon monoxide and the colour developed compared against the standard. (100% means 14·8 gm. per 100 ml).

(c) **Gower's Haemoglobinometer :** Standard used in a solution of picrocarmina Golatine (100% means 15 gm. per 100 ml).

(d) **Sahli's Haemoglobinometer :** The haemoglobin is converted into acid haematin by N/10 HCl and the colour developed matched against that of the standard (100% means 17·3 gm. per 100 ml).

(e) **Hellige's Haemoglobinometer :** Standard used is a piece of coloured glass comparator. (100% means 14·5 gm. per 100 ml).

(f) **Van Slyke's Method :** By noting the volume of oxygen that can be taken up by a known quantity of blood, when fully saturated. (1 gm, of haemoglobin when fully saturated can be taken up by 1·34 ml. of O_2),

(g) **Photo-electric Method :** The red coloured rays emitted by a solution of haemoglobin are absorbed by absorptiometer, the light energy is converted into electrical energy and the deflection of the needle is noted and the percentage of haemoglobin is calculated from a chart.

(h) **Miescher's modification of Von Fleischl's Haemoglobinometer :** This method given accurate results.

(i) **Colorimetric method :** The comparison is done with the help of a colorimeter.

Estimation of Haemoglobin : The haemoglobin is estimated by an apparatus known as Haldane's modification of Sahli's Haemoglobinometer.

Principle : Blood is diluted with HCl and the haemoglobin is converated into brown haematin hydrochloride. The brown colour is then determined colorimetrically by matching point is read on a scale and the haemoglobin content is in gms. per 100 ml. obtained directly. The instrument is calibrated by the use of standard blood supply which has been estimated photometrically.

Apparatus Required : The apparatus required for the estimation of haemoglobin are the following : (1) Comparator box with brown coloured prism. (2) Graduated tube. (3) Haemoglobinometer capillary pipette marked 20 C.m.m. for taking blood. (4) Medicine rod. (5) Glass rod. (6) Brass for washing the instruments.

Description of the Apparatus : (1) A mixing tube has got graduations upto 160 ml. at one side and 22 gms. on the other side and is opened at the top. (2) A capillary pipette with a transverse marking at 20 c.m.m. to hold that amount of blood. filled with a rubber tubing and a mouth-piece. (3) A small "drop bottle" for adding distilled water drop by drop. (4) A tube containing flat sterilised needles for pricking the finger. (5) A comparator with coloured glass at the two sides and there is a longitudinale hole for inserting graduated tube containing solution of haemoglobin. (6) A solid glass rod stirring the haemoglobin into the graduated tube for matching the colour. (7) N/10Hydrochoric acid for haemolysis.

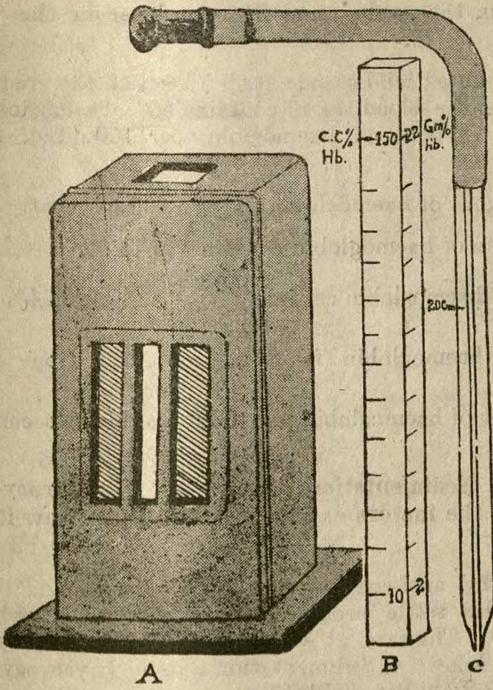


Fig. 4. Haemoglobinometer.
A—Comparator Box. B—Graduated Square Tube.
C—Capillary Pipette.

Reagents Necessary : The reagents necessary for estimation of haemoglobin are :

(1) N/10 HCl

(2) A bottle with pipette for distilled water.

Technique :

(a) The haemometer is placed on a sheet of white paper. The flap under the instrument is opened on the left and light is allowed to enter the haemoglobinometer.

(b) The watch glass is filled with N/10 HCl solution. The finger is pricked on the tip, the fiirst drop of blood is wiped away, then carefully the blood is sucked upto the mark of 20 Cu. m.m. on the capillary tube avoiding air bubbles. The excess of blood adheres to the tip or by the sides of the pipette is removed.

(c) Then continuosly N/10 HCl is upto the mark on the pipette. The rubber tube is removed from the pipette and the both end of it is carefully closed by the finger.

(d) The pipette is then gently shaked and the blood sample is dissolved in the acid. Then the entire content is transferred into the colourimeter square tube of the instrument. Then the colourimeter tube is placed on the hole of the instrument.

(e) The flap below the instrument is opened and light is allowed to enter the instrument. The colour edge with the small wheel is turned on the right side until the two fields match. Then haemoglobin value in gms. is read directly on the scale removing the lever on the eye piece.

Reading : Let the diluted fuild stands at the level ef the graduation 50 on the glass tube, the blood tested contains 50% haemoglobin. i e, half of 14·8 gms. or 7·4 gms. of haemoglobin per 100 ml. of the blood,

Calculation : 14·8 gms, of haemoglobin contain 100 per cent.

1 gm of haemoglobin contain 100/14·8%

$$12{\cdot}5 \text{ gms. of haemoglobin contain } \frac{100\times 12{\cdot}5}{14{\cdot}8}\% \text{ or, } 84{\cdot}4\%$$

∴ Percentage of haemoglobin is 84·4% obtained from the experiment.

Result : The amount of haemoglobin per 100 ml. of blood becomes 15 grams.

Q. 11. What is Sedimentation Rate of Erythrocytes or E. S. R. ? What are the factors explaining E. S. R. ? How it is determined in man ?

If blood kept fluid by anti-coagulant is allowed to stand in a narrow tube, the corpuscles settle progressively to the bottom while plasma rises to the top, The rate at which this takes place is very constant in health and is known as Sedimentation Rate of Erythrocytes or E. S. R. or Suspension Stabilitiy of Blood.

Normal Values : The normal erythrocyte sedimenation rate varies as follows : (1) It is lowest in the new born i. e. 0·5 m.m. per hour. (2) For a healthy male, it is 2 to 3 m.m. per hour. (3) For a healthy female, it is 3 to 7 m. m per hour. (4) In pregnancy, the rate of sedimentation increases.

Factors explaining the process of Sedimentation Rate : There are a number of factors which explain the process ef sedimentation rate are the following : (1) Specific gravity of plasma. (2) Viscosity of plasma. (3) The red cell volume and the amount of haemoglobin. (4) Clumping of the red cells into bigger masses.

Rise of E. S. R. : The increase in E. S. R is usually associated with an elevated fibrinogen level and occasionally with a rise in globin. The presence of an increased sedimentation rate suggests organic disease, even in the absence of other signs. It is grossly increased in conditions associated with inflammation or tissue destruction such as acute or chronic infections of any severity or severe trauma, It also increases in anaemia, pregnancy, nephrosis and malignancy.

Fall of E. S. R : The sedimentain rate is decreased in polycythaemia and congestive heart failure.

Determination of E. S. R. : The erythocyte sedimentation rate is determined either by Wintrobe's or by Westergreen's methods. In Westergreen's method, 2 ml. of blood is mixed with an anticoagulant (0·5 ml. of 3·8% Sodium citrate solution) and allowed to stand in an Westergreen sedimentation rate tube. The corpuscles settle progessively due to their greater density, while the plasma rises to the top. The length of the clear plasma at the end of the hour will give the E.S.R. which is expressed in m.m. per hour. The settling of corpuscles is resisted by the surface area of the falling particles. The cells are allowed to staed outside the body, tend to aggregate to form rouleaux (i.e. cells piled one on the top of the other, a condition where the cells are irreversibly clumped together and can not be separated); as they do so, the ratio of mass to surface area in the enlarged particles increases and as a result they sink with greater rapidity. Therefore, fundamentally, E.S.R. depends on rate of rouleaux formation.

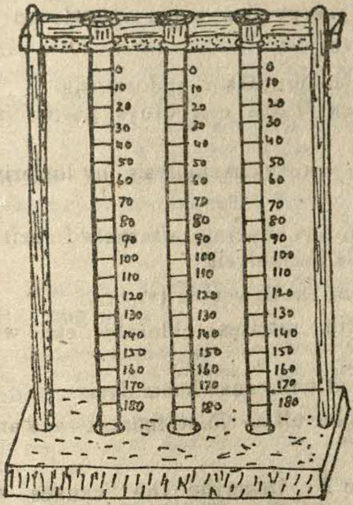


Fig. 5. Erythrocyte Sedimentation Rate Apparatus.

Q. 12. What is Haemolysis (Fragility of the Red Cells)? What are the factors causing haemolysis ?

Haemolysis is a process in which the haemoglobin content of red blood cells is discharged in the surrounding fluid when red cells are introducted in a hypotonic solution.

If we add some water to blood plasma, it becomes diluted and there will be immediate lowering of the osmotic pressure of plasma but osmotic pressure inside the red cells will remain unchanged. Thus water passes inside the red blood cells from the plasma and red cells swell up and ultimately bursts and thus haemolglobin is discharged in the surrounding solution.

Factors Causing Haemolysis : There are a number of factors that cause haemolysis are the following :

(1) Simple dilution of blood causes haemolysis.

(2) Various other chemical substances may cause haemolysis, either destroying the membrane or they dissolve the membrane. They are acids, alkalies, choloform, benzene, bile salts and ether.

(3) Bacterial toxins and parasitic toxins also cause haemolysis.

(4) Certain substances are present in the blood serum which are known as *Haemolysins* and it can cause haemolysis of the red blood cells. The blood serum of one animal can haemolyse the red blood cells of another animal e.g. Rabbit's corpuscles when introduced in human serum they are haemolysed.

(5) Water causes haemolysis by the process of endosmosis.

(6) The hypotonic saline less than 0·48% can cause haemolysis by the process of endosmosis.

(7) Bile, saponin, sapotoxin etc cause haemolysis by lowering the surface tension.

(8) The physical agents like vigorous shaking, alternate freezing, thawing, heat, x-ray, radium etc, cause haemolysis.

(9) Haemolysis is caused by adding snake venom (viper).

(10) Drugs like quinine, phenacetin, nitrites, chlorates etc. will cause haemolysis.

(11) Addition of incompatible blood will cause haemolysis.

(12) Haemolysis occurs by sunlight, ultra-violet light, x-rays and radium.

Q. 13. What is Haemorrhage? Describe the causes of haemorrhage.

When an artery or vein is cut open, haemorrhage occurs. When a vein is cut, loss of blood takes gradually and slowly. Even 10% of the total blood may be eleminated without much bad effect. But when more than this amount of blood is lost, blood volume is diminished and there is appreciale fall of blood pressure, as a result of which the circulation through brain and other tissues is diminished, as blood pressure maintains the normal circulation through all these tissues.

Causes of Haemorrhage:

I. **Predisposing Causes:** (1) Separation of *sheath of an artery* for long distance leading to separation of vasovasorum causing necrosis of the vessel wall which will lead to bleeding. (2) *Arterio-sclerosis*: In this condition, the vessel walls become fibrosed due to the deposition of circulating ionised calcium on the wall of the vessels. This condition is generally occur in old age (3) *Haemorrhagic Diseases*: There are haemophilia, purpura etc. which will cause haemorrhage (4) *Deficiency of Vitamin C and K*. It will cause haemorrhage as in scurvy.

II. **General Causes**: (1) *Trauma*: Bleeding from the nose known as Epistaxis, bleeding from mouth known as haematomesis and bleeding from rectum known as Malena (2) *Constitutional Disorders*: These will cause haemorrhage as in Haemophilia, Purpura Scurvy etc.

(3) *Secondary to pathologicol change in vessel wall* : This will cause haemorrhage as in Aneurism, Athroma etc. (4) *Hypertension* causing high blood pressure. (5) Failure of natural arrest of bleeding.

III. **Exciting Causes** : (a) *Infective Causes* : (1) Necrosis of the terminal stump following ligation of the artery. (2) Proteolytic ferment liberated by the micro-organism causing disolution of the catgut of the wound. (3) Infection hinders the transformation of the temporary clot into a permanent one. (b) *Non-infective causes* : Sir John Mekin's Theory states that high blood pressure will cause pressure on the lateral wall of the vessel lead to aneurysm that will follow rupture and cause haemorrhage.

Some Important Indices about Red Blood Cells and Haemoglobin :

Certain absolute values are found out from the red cell count, haemoglobin percent in grammes and relative corpuscular volume. These absolute values are the following :

1. **Colour Index** (C.I.) : It is calculated as percentage of Haemoglobin divided by percentage of Red blood cells. Suppose the haemoglobin content is 15 gm. per 100 ml. and the number of corpuscles is 5 millions per c.m.m., so the colour index will be 1. When red blood cells present is 5 million, it is known as 100 percent and 2½ millions as 50 present. The colour index varies from 0·8 to 1. In pernicious and hyperchromic anaemia, the colour index is greater than normal. In hypochromic anaemia, it is less than normal.

2. **Mean Corpuscular Volume** (M.C.V.) : This is the mean or average volume of a single red cell. It is expressed in cubic microns (c. μ) and is obtained by dividing the packed cell volume by the cell count :

$$=\frac{\text{Vol. of Packed Red Cells in ml. per litre}}{\text{Red Blood Cells in millions per c.m.m.}}=87 \text{ Cubic } \mu \pm 7.$$

3. **Mean Corpuscular Haemoglobin** (M.C.H.) : This is the mean or average haemoglobin content of a single red cell expressed in micro-microgrammes ($\gamma\gamma$) and is determined as ;

$$\frac{\text{Haemoglobin in grammes per litre of blood}}{\text{Red Cells in millions per c.m.m.}}=29{\cdot}5\gamma\gamma \pm 2{\cdot}5.$$

4. **Mean Corpuscular Haemoglobin Concentration** (M.C.H.C) :

This is the mean or average of the haemoglobin concentration in each cell and is expressed as a percentage of the cell contents. It is determined as :

$$\frac{\text{Haemoglobin in grammes per 100 ml.}}{\text{Volume of packed red cells in 100 ml.}}\times 100=35\% \pm 3.$$

5. **Saturation Index** : It indicates the concentration of haemoglobin in the red blood cells and is obtained as :

$$\frac{\text{\% of Wt. of Haemoglobin per 100 ml.}}{\text{\% of Corpuscular Volume}}=1. \text{ (Range 0·9 to 1·1)}$$

6. **Packed Cell Volume** (P.C.V.) : The packed cell volume may be determined by centrifuging whole blood with added anticoagulant heparin in Haematocrit. It is expressed as a percentage of the whole blood volume. The normal values are in men 40% to 54%, in women 36% to 47%, in infants 44% to 62%, in children of 1 year 35% and children of 10 years 37·5%.

Q. 14. Describe the varieties, origin, fate and functions of Leucocytes or White Blood Corpuscles.

The white blood corpuscles are one of the celluar elements of blood which are nucleated and serve mainly the defensive functions of the body.

Varietis of Leucocytes : Leucocytes are of two types broadly known as granulocytes and agranulocytes.

A. **Granulocytes :** Protoplasm contains granules. These are divided into three groups according to the staining reactions of their granules.

(*a*) **Neutrophil cells or Polymorphonuclear Leucocytes :** It contains a lobed nucleus and protoplasm with abundant fine neutrophil granules which stain with Enrlich's tri-acid and with the May-Fiemsa stains. Granules are quite small and are stained a violet tint with neutral dyes. Cytoplasm contains proteolytic enzyme capable of causing autolysis It is 10 to 12 µ in diameter and contains about 68 to 70%. The absolute number becomes 3000 to 6000 per cu. m.m. The cells are actively amoeboid and phagocytic. They are capable of locomotion and ingest foreign particulate matter.

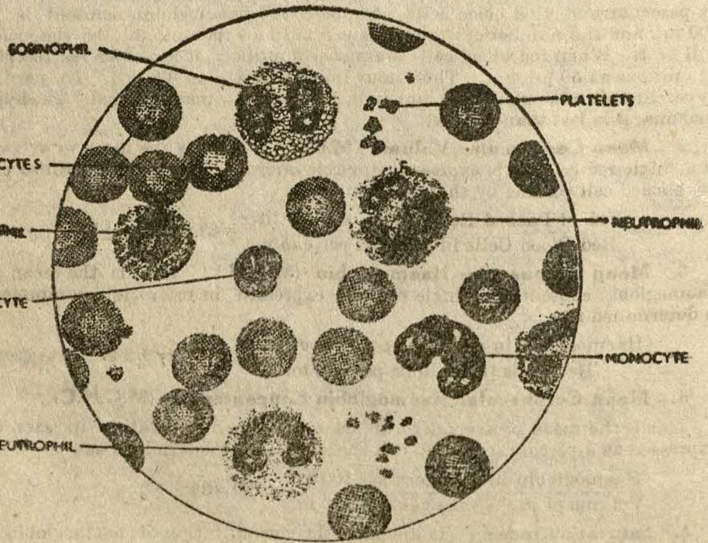


Fig. 6. Normal blood picture under the microscope showing Red Blood Corpuscles (Erythrocytes), White Blood Corpuscles (Leucocytes) and Platelets (Thrombocytes).

(*b*) **Eosinophil cells :** They stain with acid dyes like eosin. It is present about 3 to 4%. The absolute number becomes 150 to 400 per cu. m.m. The nucleus is generally single but is often crescent–

shaped or renifom or bilobed. Protoplasm is crammed with large, discrete, highly refractive granules which stain deeply with eosin and give micro-chemical reactions for iron as well as phosphorous. It is 10 to 12 μ in diameter. The granules are oval, much coarser and stainer a bright red with eosin.

(*c*) **Basophil cells or Mast cells :** These are strined with basic dyes like methylene. They are present about average 0·5% or less. The absolute number becomes 0 to 100 per cu. m.m. These have a lobed nucleus and present in their protoplasm a number of granules which stain deeply with basic days. These are somewhat smaller than the polymorphonuclear cells and about 8 to 10 μ in diameter. They have got ameboid mevement and are supposed to secrete heparin.

B. **Agranulocytes :** The granules are absent in these cells. They are of two types known as monocytes and lymphocytes.

(*a*) **Monocytes :** They are present about 5 to 6%. The absolute number becomes 350 to 800 per cu. m.m. The nucleus is round or oval when the cells are young but it becomes convuluted, kidney-shaped or horse-shoe shaped when the cells grow older. These are large vocuolated cells with a single nucleus and with fairly abundant faintly granular cytoplasm. They are 10-15 μ in diameter. They have the property of ingesting foreign particles.

(*b*) **Lymphocytes :** They are present about 23 to 25%. The absolute number becomes 1500 to 2700 per cu. m.m. They are of two types—small and large lymphocytes. They possess rounded nucleus and a small amount of cytoplasm which has very few granules. They are abundant in number and smaller than the other mononucleated white cells which are about 8 μ in diameter. They serve as a phagocytic agent

Origin or Development of Leucocytes :

(*a*) **Reticular cell :** Leucocytes are developed from reticular cells which are nucleated, irregular, having basophilic cytoplasm and no mitochondria or granules.

(*b*) **Primitive white blood corpuscles :** These are coming from reticular cell, found outside the blood vessels of bone marrow of lymphoid structure. They are spherical in shape and possess a nucleus. It is developed into myeloblast cell.

(*c*) **Myeloblast cell :** It contains a big nucleus with several nucleolus and chromatins. The mitochondrial granules are present in the cytoplasm.

(1) Granules in some myelocytes are stainable with neutral dyes and they are called neutrophil myelocyte.which in turn give rise to neutrophil cell.

(2) Granules in some myelocytes are stainable with eosin dye and they are eosinophilic myelocytes which in turn give rise to eosinophil cell.

(3) Granules in some myelocytes are stainable with basic dyes as haemotoxylin and they are called basophilic myelocytes which in turn give rise to basophil cell.

(*d*) **Lymphyblast and Monoblast cells**: These are developed from lymphoid structure and reticulum cells of spleen. They develop lymphocyte and monocyte. The lymphocytes are of two varieties known as large and small lymphocytes. The monocytes are of large and transitional. The lymphoblasts may, in turn, differentiate along one of three possible lines. Firstly, they may form *young lymphocytes*, secondly, they may form *monoblasts* and then *monocytes*. and thirdly, they may form *plasmoblasts* and then plasma cells.

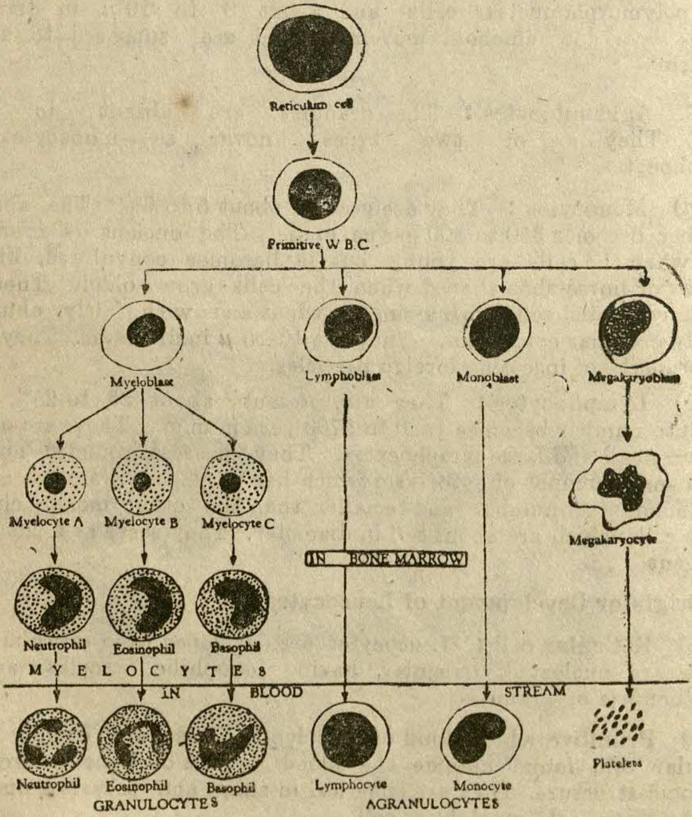


Fig. 7. Stages of Development of Leucocytes and Platelets,

Life and fate of Leucocytes :

All the white blood corpuscles remain in the blood stream for 1—5 days after their formation, after which they are distintegrated and and disappeared in the blood stream. Some white blood cells are killed in the fight against bacteria. These disintegrated white blood cells are ingested by the phagocytic cells of the reticulo-endothelial cells.

Functions of Leucocytes :

(1) **Phagocytosis** : The white blood cells engulf foreign particles and bacteria and generally digest them. By this process it serves the great defensive functions.

(2) **Antibody formation** : The lymphocytes manufacture antibody by producing immune bodies associated with y-globulin fraction. It helps in defensive action against any foreign bacteria,

(3) **Manufacture of Trpysin like enzyme** : The neutrophil manufactures trypsin like enzyme. It helps in the digestion of bacteria in dead tissue.

(4) **Magufacture of Pepsin** : Lymphocytes and monocytes elaborate pepsin like enzyme. They liquify solid dead tissue.

(5) **Manufacture of Trephone-like substance** : The leucocytes manufacture trephone like substances from plasma protein which help in nutrition, growth and repair of the fresh tissue.

(6) **Secretion of Heparin** : The basophil secretes heparin which prevents intra-vascular clotting.

(7) **Anti-histaminic function** : The eosinophils are very rich in histamine content which prevents all short of allergic conditions that occur in daily day life.

(8) **Formation of Platelets** ; These are formed from the fragments of the disintegrated white blood cells,

(9) **Formation of Plasma Protein** : The cytoplasmic remnants of the dead leucocytes form albumin and globulin part of plasma protein.

(10) **Formation of Fibroblast** : The lymphocytes may be converted into fibroblast in an area of inflammation and thus help in the process of repair of those inflammatory areas.

Q. 15. Describe the origin, properties, fate and functions of Thrombocytes or Blood Platelets.

Platelets are non-nucleated, round or oval bodies having various sizes, the average being 2·5μ, performs blood coagulation and repairs carpillary endothelium.

Histology : The platelets comprise of clear ground substance known as *hyalomere* and deeply staind central portion known as *chromatomere*. The chromatomere consists of alpha granules, mitochondria, sydersomes, serotonin-containing granules, glycogen granules, Ribosome etc.

Origin : As regards development about blood platelets there are many views :

(1) Most histologists regard that the platelets are derived by fragmentation from the cytoplasm of the giant cells or megakaryocytes of the bone-marrow. However, in every hyperplastic marrow it appears that platelets are formed within the body of megakaryocytes and released by rupture of the cellular membrane. (Fig. 7.).

(2) It is possible that giant cells in the lungs also produce platelets because blood coming from the lungs contains a larger number of platelets than venous blood going to the lungs. On the otherhand, there is a reduction in the number of platelets as the blood traverses the systemic circulation.

(3) The platelets are derived from the fragments of those senile leucocytes which disintegrate in the circulation.

(4) Platelets are derived from monocytes and extruded nuclear material of monoblast.

(5) From myeloblast, blood platelets may be originated.

Properties : (1) The platelets are sticking to water wettable or injured surface. (2) They help for easy clumping. (3) They are easily disintegrated and thus liberates thrombokinase.

Fate of Platelets : (1) Platelets will die after four days. (2) They are destroyed in the spleen and other reticulo-endothetial cells.

Functions of Platelets :

(a) **Blood Coagulation** : When blood is shed, the platelets disintegrates and liberates thrombokinase which combines with prothrombin and calcium ion, converts into thrombin and initiates blood clotting.

(*b*) **Repair Capillary Endothelium** : During circulation, the platelets adhere the damaged endothelial lining of the blood capillaries and repairs in a very speedy way.

(*c*) **Clot Reaction** : The number of platelets are directly proportional to the speed of clot reaction and thereby helps in the process of clot reaction.

(*d*) **Acts as a Vasoconstrictor** : When platelets disintegrates during the process of coagulation, histamine and serotonine (5-hydroxy tryptamine) are released. The latter substance is a potent vasoconstrictor and it is responsible for the constriction of the minute vessels which is an important factor in the initial stages of hæmostasis.

Q. 16. Describe the composition, varieties and properties of Plasma Protein.

Blood is a liquid connective tissue which comprises 55%plasma and 45% cellular elements. Plasma is the liquid protion of the blood which contains protein and the protein part of plasma is known as plasma protein.

Composition of Plasma Protein :

Fractionation by Electrophoresis.		Fractionation by salting out with Sodium Sulphate.	
	grams/100 ml.		grams/100 ml.
Total Protein ;	6·03—6·72	Total Protein :	6 0—8·0
Albumin ;	3·82—4 40	Albumin :	4·3—5·0
Total globulin :	2·23—2·29	Total globunlin :	1·1—3·1
α—globulin :	3·79—0·84	Engloblin ;	0·1—0·4
β—globulin :	0·78—0·81	Pseudoglobulin :	1·0—2·7
γ—globulin :	0·66—0·70	Fibrinogen :	0·2—0·3
Fibrinogen :	0·44—0·43	Albulin/globulin ratio :	1 50
Albumin/globulin ratio ;	1·00		

Varieties and Seperation of Plasma Protein :

(*a*) **Serum albumin** : It constitutes the major part of the total plasma protein. It is albumin in nature having a molecular weight of 70,000. It is soluble in distilled water and precipitated by full saturation with ammonium sulphate having isoelectric point (pH 4·9).

(*b*) **Serum globulin** : It is globulin in nature having a molecular weight about 170,000. It is insoluble in distilled water but soluble in salt solution. It is coagulated at about 70°C and precipitated by full saturation with magnesium sulphate, half saturation with ammonium sulphate and not precipitated by sodium chloride at all having pH 6·3.

(*c*) **Fibrinogen** . It is globulin in nature but has a bigger molecule than serum globulin being the molecular weight about 450,000. It is coagulated at about 56°C and precipitated by ¼th. saturation with ammonium sulphate and half satution with sodium chloride. It is insoluble in distilled water having pH 5·3.

(*d*) **Prothrombin** : It is found in the circulating blood as an inactive form. The prothrobin is converted into thrombin with the activation of calcium ion and thrombokinase. It is probably furnished by the blood platelets, the bone marrow and possibly by the lymph glands too.

Properties of Plasma Protein :

Only those properties which need be known to understand the methods of separating the proteins of the plasma and their physiological properties will be considered here.●

(*a*) **Precipitation by salts** : Different proteins are precipitated from solution by addition of salts of different concentration.

(1) Globulin can be separated by half saturation with ammonium sulphate. Euglobulin I is insoluble in water at pH 6 and can be precipitated by carbon dioxide. Pseudoglobulin is soluble in water but can be separated by half saturation with ammonium chloride or ammonium sulphate.

(2) Fibrinogen can be separated by half saturation with sodium chloride. Prothrombin can be preceipitated by acidifying a plasma and adjusting the pH at 5.

(3) Albumin can be precipitated by half saturation with ammonium sulphate.

(*b*) **Fractional precipitation** : In order to isolate individual plasma potein in quantity, *E. J. Cohn* has devised method on fractionation with low salt concentration at low temperatures, varying the pH and modifying conditions by the addition of alcohol.

(*c*) **Sedimentation in the Svedberg Ultracentrifuge** : Different proteins are sedimented at different rate when solution of them are in high speed in the ultra centrifuge separation.

(d) **Iso-electric Point** : Proteins can behave as bases or as acids owing to the fact that their constituents—the amino-acids contain both basic (NH_2) and acid (COOH). In alkaline solution, Paotein behaves as an acid and in acid solution it behaves as a base. Thus the protein molecule has the tendency to move towards the cathode or anode according to the nature of solution. In certain pH neither as an acid nor as a base it is unionised and does not move towards the cathode or towards the anode. Thus pH is called iso-electric point. In albumin, it is 4·7 and globulin, it is 5·7.

(*e*) **Electro-phoretic mobility** : The plasma protein can be separated by means of electrophoresis If the force of electric field is applied to the protein molecule, then it tends to move either to the cathode or to the anode according to the nature of solution. By this method it has been found that albumin possesses the highest mobility and euglobulin has the least mobility,

(*f*) **Buffer action** : By its buffer action, it helps to maintain the pH of blood constant. They are probably reponsible for less that to the total buffer action of blood.

(*g*) **Molecular weight** : The molecular weight of albumin is 70,000 ; globulin 170,000 and fibrinogen 450,000 and the molcular weight is related to their size. Large molecule pass less readily smaller molecule through capillary walls.

(*h*) **Osmotic pressure** : The osmotic pressure of plasma protein is 25 to 30 m.m. mercury, Thus protein depends mainly on albumin and to a less extent on serum globulin. The smaller the molecule of protein, is the number of molecule in a particular quantity and greater in osmotic pressure.

(*i*) **Viscosity :** To resistance to the flow of fluid at constant viscosity through a capillary of constant bore depends almost entirely upon the viscosity of fluid. The viscosity of protein solution depends for more on the shape of the protein molecule than its size. Less symmetrical is that the molecule, greater is its viscosity.

Q. 17. Describe the origin, fate and functions of Plasma Protein.

Blood is a liquid connective tissue which comprises 55% plasma and 45% cellular elements. Plasma is the liquid portion of the blood which contains protein and the protein part of plasma is known as plasma protein,

Origin of Plasma Protein :

I. **Foetal origin :** In the embryo, the primitive plasma and plasma protein are produced, either by secretion or actual solution of mesenchyme cells. The albumin fraction is first to be formed and the other varieties appear later.

II. **Adult origin ·** In adult orign of plasma protein, the following are the source of formation :

(a) **From liver :** Serum albumin and proteins concern in blood coagulation are probably formed by the liver. The food protein splits up into amino-acids and goes to the liver and in the liver, plasma proteins are formed from the amino-acids and all the amino-acids are not converted into plasma protein.

(b) **From reticulo-endothelial system ;** Serum globulins are probably formed widely in the body perhaps by reticulo-endothelial system and by lymhoid nodules.

(c) **From disintegrated leucocytes :** The white blood corpuscles always undergo disintegration and certain amount of proteins are also discharged into the blood,

(d) From the general tissue cells.

(e) From bone-marrow.

(f) According te *White* and *Dougherty*, the adreno-corticotropic hormone of the Anterior pituitary gland through its action on the adrenal cortex affects the manufacture of β-and γ-globulins.

Fate of Plasma Protein ;

The plasma protein finally converts into tissue protein. *Whipple* suggests that the protein of the cells can be divided into three categories : (1) Fixed cell protein which is indispensible for cell life or activity (2) Dispensable reserve protein which can be called upon for energy and other purposes in starvation. (3) Labile reserve protein which can be readily turned out into the blood stream to maintain the plasma prorein concentration.

Functions of Plasma Protein :

(1) Protein helps in the formation of blood coagulation. Prothrombin combines with calcium ion and thromhoplastin forms thrombin which is one of the essential factors for blood coagulation. Fibrinogen which is one of the essential elements of plasma protein which combines with thrombin and froms a fibrin network that entangles corpuscles forms clot.

(2) Protein is concerned in plasma colloidal osmotic pressure, The osmotic pressure of plasma is 25 m.m. and it regulates the interchange of fluid between the blood and tissue. If the osmotic pressure of the titsue rises, the fluid passes from the blood and it so, protein of blood rises the fluid passes to the blood. If the osmotic pressure of blood becomes low, the fluid passes out of blood in the tissue spaces.

(3) Protein gives certain degree of viscosity and also regulates the blood pressure.

(4) The Euglobulin absorbs bilirubin, the resulting compound being responsible for the indirect Vandenbergh Reaction.

(5) Plasma protein acts as a buffer and thus it regulates the reaction of blood.

(6) The globulin and fibrinogen fraction influence the tendency of corpuscles to adhere one another and forms clumps.

(7) Globulins have got a capacity for protection from bacterial infection of Diphtheria, Typhoid and Influenza. They take part in the formation of antibody in the blood.

(8) They serve as a reserve of protein upon which for a time tissue can draw it during fasting or when protein intake is inadequate.

(9) Protein regulates the sedimention rate. If fibrinogen and globulin concentration is high, the sedimentation rate is increased. It has got clinical importasce.

(10) It regulates the interchange of fluid from the blood to the tissue and vice-versa,

(11) It helps for the carriage of carbon dioxide as a from of carbamino-compounds.

(12) Plasma protein helps in the transport of a number of materials such as lipids, drugs and metals, many of whcih appear to travel in the blood associated with one or more specific proteins.

Q. 18. What is Coagulation ? What are the factors necessary for Coagulation of Blood ? Describe the theories of Coagulation of Blood.

Coagulation is a built-in mechanism of the blood to save man from losing all his blood after an injury. It is a physico-chemical phenomenon by means of which the continuous bleeding is stopped from the wound or any injured parts of the body. The physical process being the change of fluidity into solidity and the chemical process being the conversion of prothrmbin into thrombin and fibrinogen into fibrin that forms of fine meshes of network in which the cellular elements of blood get entangled and the fluid portion of a fine straw coloured liquid known as serum is separated out. This entangled mass is known as clot and the whole procefs is known as coagulation.

Factors Necessary for Coagulation :

There are a number of factors that concerned in the process of coagulation. Most of the factors are internationally accepted in 1954 but a few of them are not accepted as yet.

(1) **Factor I or Fibrinogen** : It represents 5% of the total plasma protein. It is easily precipitated from plasma by addition of a sulphate with one third of its volume at 0°C. The deficiency disease is known as congenital afibrinogenaemia when the patient bleed profusely after undergoing an operation.

(2) **Factor II or Prothrombin** : It is a precursor of thrombin. The prothrombin can easily be converted to thrombin when the precipitate is redissolved in the buffer at pH 7 and a solution containing calcium ions is added.

(3) **Factor III or Tissue Thromboplastin or Tissue emulsion** : It was the first substance recognised as catalising the coversion of prothombin to thrombin in the presence of calcium ions. A deficiency of this tissue factor is unknown in man or animals.

(4) **Factor IV or Calcium** : The ionised calcium is essential for the physiological conversion of prothrombin to thrombin. A bleeding diathesis due to deficiency of ionised calcium is unknown in man.

(5) **Factor V or Pro-accelerin** : (Labile factor or Accelerator globulin) : It is essential for rapid and complete prothrombin conversion by either the extrinsic or the intrinsic process. This factor is not absorbed in aluminium hydroxide, barium sulphate or barium chloride. It is much more unstable than prothrombin in stored, citrated and particulary oxalated blood.

(6) **Factor VI or Accelerin** : It is formed when traces of thrombin appear. Its activity is only demonostrable during the early stages of coagulation.

(7) **Factor VII or Pro-convertin** (Stable factor or Serum-prothrombin conversion accelerator, SPCA or Auto-prothrombin I) ; This factor is required for the extensive activation of prothrombin to thrombin using tissue emulsion. It is a protein closely associated with prothrombin when it is precipitated from plasma.

(8) **Factor VIII or Anti-heamophilic Factor**, AHF (Antihæmophilic globulin, AHG or Platelet Co-factor I or Thromboplastinogen or Plasma-thromboplastic factor A or Facteur anti-hæmophilique A) ; This tactor is only necessary for intrinsic thromboplastin formation.

It is a protein which is closely associtted with fibrinogen wher it is precipitated but it disappears when the fibrinogen is highly purified.

(9) **Factor IX or Christmas Factor,** CF (Plasma thromboplastin component, PTC or Platelet co-factor II, Anti-hæmophilic factor B or Auto-prothrombin II or Plasma thromboplastic factor B or Facteur anti-hœmphilique B) : It is only necessary for intrinsic thromboplastin formation. It can be absorbed and eluted from aluminium hydroxide, barium sulphate and barium chloride. The congenital christmas factor deficiency shows clinical symptoms like classical hæmophilia.

(10) **Factor X or Stuart-Prower Factor** : It was first described by *Hoegie* in 1957. It can be absorbed and eluted from aluminium hydroxide, barium sulphate and barium chloride and can be detected in plasma and serum.

(11) **Factors XI** or **Plasma-thromboplastin Antecedent** (**PTA**) : This factor is concerned with the early stages of instrinsic thromboplastin formation. It is present in an inacctive state in plasma and required the Hageman factor for its activation. It is essential for clumping of plateles during coagulation.

(12) **Factor XII** or **Hageman Factor, HF** (Surface factor or Contact factor or Clot promoting factor) : It is present in fresh normal plasma as an inactive precursor. It is strongly absorbed on to glass surfaces and subsequently reacts with PTA.

(13) **Factors XIII** or **L.L.F.** (Laki-Lorand factor ar Fibrin-Stabilizing factor or Fibrinase) : It is present in the plasma and inhibits depolymerization of fibrin. So it stabilizes the fibrin once it is formed,

Process of Coagulation : The process of coagulation is performed by following stages :

(a) **Stage of Chemical Reaction** : At first the minute fine granules of fibrin join each other to form needles, These needles are unlike together to form long threads and they cross one another to form network.

(b) **Stage of Soildification** : The red and white cells become entangled by the mesh work and solidified to possess a jelly like mass.

(c) **Stage of Retraction** : The clot gradually reacts and a pale, yellow straw coloured fluid called serum seperates out from the entangled mass and this serum will not be clot again.

Theories of Coagulation :

A. **Morawitz's Theory** : This is the first theory of coagulation, which shows the process of blood coagulation. Prothrombin, calcium ion and fibringen are normally present in the blood but can not help in the process of coagulation, When blood is shed the platelets liberate thromboplastin or thrombokinase with prothrombin and calcium ion, forms thrombin. Thrombin combines with fibrinogen, forms fibrin The fibrin network entangling corpuscles forms clot. This theory can be summarised in the following :

Before Shedding of blood : Prothrombin+Calcium ion+ Fibrinogen→Nil.

After shedding of blood :

1. Prothrombin+Calcium ion+Thrombokinase→Thrombin.
2. Thrombin+Fibrinogen→Fibrin.
3. Fibrin network+Corpuscles→Clot.

B **Howell's Theory** : *Howell* noticed that there are two compounds of prothrombin known at Prothrombin A and Prothrombin B. In addition to that there are a number of anticoagulants known as Heparin, Hirudin and Oxalate etc. help in the process of blood coagulation. The process of blood coagulation by Howell is summarised as follows :

Before shedding of blood : Prothrombin A+Prothrombin B+ Calcium ion+Heparin+Fibrinogen→Nil.

After shedding of blood :

Prothrombin A + Prothrombin B
Fascilated by | Inhibited by Oxalate
Calcium ion ↓
Thrombin
+
Fibrinogen
Fascilated by | Inhibited by Heparin
Thrombokinase ↓
Fibrin Network
+
Entangled Corpuscles
↓
Clot

C. **Medern Theory** : This theory was established by *Biggs, MacFarlane* is 1957. There are a number of factors concerned in the process of coagulation which are prothrombin, fibrinogen, calcium ion, thromboplastin, factor V, factor VII, factor VIII and factor IX. The process of coagulation is as follows ;

1. Factors IX+Calcium ion+Factor VIII=Product I
2. Product I+Platelet=Platelet factor.
3. Platelet factor+Factor V or (Tissue factor+Factor V+ factor VII)=Thromboplastin.
4. Thromboplastin+Calciuum ion+Prothombin=Thrombin.
5. Trombin+Fibrinogen=Fibrin network.
6. Fibrin network+Entangled Cropuscles=Clot.

D. **Recent Theory** : (Breckenridge and Ratnoff) : The process of coagulation is an *Extrinsic mechanism* (Tissue factor) where the coagulation reaction sequence is called a cascade and is autocatalytic, that it, once the first step is initiated, the rest of the steps follow sequentially being catalysed by the previous steps. The cascade as proposed by *Breckenridge* and *Ratnoff* in 1965, shows that a sequential conversion of pro-enzymes or inactive precursors of enzymes to active enzymes occurs after the first step is initiated. The active enzymes are proteolytic in nature and catalyse reactions in which a small peptide fragment is removed from the inactive enzyme converting it to an active enzyme. All the factors are present in inactive form in the circulating blood. This is called *Intrinsic mechanism* (Plasma factor). A foreign body like a virus or a bacterium or an outgrowth in the blood vessel can stimulate factor XII leading to a clot.

Q. 9. Describe the mechanism of Coagulation. Describe the factors that hasten and prevent coagulation. What do you mean by Bleeding time and Coagulation time ?

The actual process involved in the coagulation of bloood have been shown to be the conversion of prothrombin to thrombin and the action of thrombin upon fibrinogen to form fibrin. On standing the fibrin network entangles corpuscles and squeeze serum from the clots. The various processes and factors involved in blood coagulation may be outlined as follows :

I. **Prothrobin activation stage :** As blood corpuscles come over injured tissue, platelets undergoes various metamorphosis and liberate phospholipide which in combination with plasma protein factor and calcium ion, form thromboplastin. The thromboplastin acts prothrombin to form serum thrombin.

(1) Metamorphosed platelets after disintegration→Platelet factor III.

(2) Platelet factor III+Plasma protein factors+Calcium ion→Thromboplastin.

(3) Thromboplastin+Prothrombin→Thrombin.

This thrombin then acts upon plasma accelerated globin to form serum Ac-globulin.

(4) Thrombin+Plasma Ac-globulin→Serum Ac-globulin.

Serum Ac-globulin then enormously increases the speed of thrombin formation from prothrombin by thromboplastin and calcium ion.

(5) $\text{Prothrombin}+\text{Thromboplastin}\xrightarrow[\text{Serum Ac-globulin}]{\text{Calcium ion}}\text{Thrombin.}$

Thrombin produces initially and increases the speed to various metamorphosis of the platelets to afford more thromboplastin formation for the coagulation process.

(6) $\text{Platelets}+\substack{\text{Thrombin}\\ \text{Surface cotact}}\rightarrow\text{Platelet factors.}$

When 10 to 20% of the plasma prothrombin has been converted to thrombin, coagulation involving transformation of fibrinogen to fibrin. This fibrin network entangling corpusles form clot.

II. **Conversion of Fibrinogen to Fibrin :** The proteolytic enzyme thrombin acts upon fibrinogen to form fibrin monomer and peptides A and B

(1) Fibrinogen+Thrombin→Fibrin monomer+2 peptide A+2 peptide B.

Fibrin monomer then polymerise to form fibrin

(2) Fibrin monomer→Fibrin polymer or Fibrin.

The fibrin polymer then interacts with calcium ion to form more solidified physiologic fibrin of the clot.

(3) Fibrin polymer+Calcium ion→Calcium ion-fibrin or Physiologic fibrin.

Factors Hastening Coagulation : There are a number of factors responsible for hastening coagulation which are the following : (1) Application of warmth such as water about 5° above body temperature. (2) Contact with water wettable surface. (3) Addition of foreign bodies into a sample of blood. (4) Addition of thrombin. (5) Rapid intravenous injection of thromboplastin or thrombokinase. (6) Adrenaline injection. (7) Addition of calcium chloride. (8) Injection of biological products. (9) Injection of Vitamin K.

Factors Preventing Coagulation : There are a number of factors responsible for preventing coagulation which are the following : (1) Lowering the temperature. (2) Avoiding contact with injured tissues. (3) Removal of calcium ions. (4) Application of cold prevents coagulation. If horses's blood, which always clot slowly is cooled rapidly in between 0°C to 1°C, it remains fluid for an indefinite time. (5) Methods involving with neutral salts : (i) 25% solution of Magnesium sulphate. (ii) Equal volume of half saturated sodium sulphate solution. (6) Methods depending on decalcification of blood by sodium fluoride (0·3%) or sodium citrate (0·35%). (7) Methods depending on the use of certain substances of animal or plant origin. (i) Peptone plasma. (ii) Leech extract or hirudin. (iii) Heparin. (iv) Dicumarin—present in spoiled sweet clover causes reduction of blood coagulability after few days. (8) Methods depending on the use of synthetic organic substances : (i) Chicago blue—injected intravenously or added to blood in vitro that prevents coagulation. (ii) "Bayer 205" (Germanine) or Licuoid—injected intravenously, also causes incoagulability of blood.

Coagulation Time : Puncture the tip of a finger and draw from prick blood into capillary tube noting the time of prick at 0 time. Every half a minute, snap off tenth part of capillary tube very gently and note time when a clot appears as shown by stringy thread tending to keep united the ends of the capillary tube when broken. The coagulation time requires 3 to 10 minutes. In hæmophilia, coagulation time is increased very much.

Note.: (1) The normal coagulation time in man is about 3 to 5 minutes It is prolonged in deficiencies of factors V, VIII or IX. (2) The capillary tubes chosen should be of equal diameter. (3) The blood clots factor in narrower capillary tubes.

Bleeding Time : The time taken for a pricked ear, dried off with blotting paper every quarter of a minute, to stop bleeding is known as the *Bleeding time*, which varies from 2 to 4 minutes. It depends not only on coagulability but the power of injured capillary fo contact. When bleeding time varies but the coagulation time is not affected which is seen in case of a disease of purpura.

Note : (1) The normal bleeding time in man is about 1 to 3 minutes. (2) The stoppage of bleeding depends mainly on capillary contraction. (3) In *Purpura*, the coagulation time is normal but has prolonged bleeding time. The bleeding tlme is normal is *Haemophilia.* (4) The bleeding time is abnormally prolonged in platelet defieciency and ascorbic acid deficiency.

Q. 20. Why does not blood clot in the vessels ?

The blood does not clot in the vessels because intact vascular endothelium in the blood vessels, constant flow of blood and presence of natural anticogulant like heparin.

Explanations : There are a number of opinions about the non-occurrence of coagulation of blood in the vessels which are given below :

(*a*) **Morawitz's Idea :** There is no coagulation in the vessels because all the essential constituents of blood are present in the circulating blood. Morawitz said that it is due to presence of two small amount of thrombokinase in the circulating blood. After blood is shed, platelets give rise to large amount of thrombokinase and clottting occurs,

(*b*) **Howell's Idea :** The presence of an anticoagulant like heparin in the blood, maintains the normal fluidity of blood inside the vessels. Heparin, when treated with the constituents of blood like prothrombin, fibrinogen, thrombokinase etc in vitro, has no anticoagulation action. It neither inhibits the conversion of prothrombin into thrombin, nor neutralises thrombin or thromboplastin. Yet in blood, it acts as a powerful anticoagulant, prevents the conversion of prothrombin into thrombin and also acts as an anti-thrombin. A co-factor known as serum albumin factor is essential. Heparin, if injected, is rapidly excreted in the urine, and destroyed in the tissues. Incoagulability in vivo can therefore only be maintained by continuous or frequent administration of heparin.

Q. 21. What is Blood Volume ? What are the factors essential for influencing blood volume ? Describe the different methods of determination of blood volume.

The blood volume of a man of average weight of 70 Kg. is nothing but the amount of blood present in our body i.e. 5 litres or $\frac{1}{11}$th. part of the total body weight or roughly 7% of the body weight. Blood volume estimations are of value in many clinical conditions associated with a loss or gain of fluid by the body, or for the purpose of checking the results of corpuscular and haemoglobin estimations.

Normal Blood Volume ;

(a) **In relation to body weight :** The volume of the blood in normal subjects like male and female is 70 to 100 ml. per Kg. body weight ; that of the plasma is 40 to 60 ml. per Kg. The total blood volume is about one-eleventh of the body weight or 6 litres in an average adult.

(b) **In relation to body surface :** Per square metres of body surface the volume of the blood is 2500 to 4000 ml. and of the plasma 1400 to 2500 ml. the average 1·82 litres in males and 1·64 litres in females.

Factors influencing Blood Volume :

(1) **Muscular exercise :** During muscular exercise, blood volume is increased due to the liberation of adreneline.

(2) **Emotional exctiement :** In this condition, there will be contraction of the spleen and as a result, the stored corpuscles will circulate the blood increasing the blood volome.

(3) **Injection of desoxycorticoid :** These will cause increased reabsorption of sodium from the kidney tubules and with these large amount of water will be reabsorbed into the blood, thereby increasing the blood volume.

(4) **Large amount of water :** The large amount of water will be lost in diarrhoea and vomiting and thereby blood volume will be diminished.

(5) **Severe starvation ;** During severe starvation blood volume falls slightly in absolute figure but increases greatly in relation to body weight.

Methods for determination of Blood Volume :

1. **Direct Method :** This method is applicable in lower animals.

A. **Welcker's Method** (1854) : (1) An animal is bled to death and the blood collected from a cut artery. (2) Then its blood vessels are washed out by pumping normal saline solution *i e.*. Locke's solution into the vessels. The saline washings are added to the already collected blood, (3) The colour of this mixture is matched against the sample of normal blood of the same animal. From its data the volume may be calculated. In dogs, the total blood volume is 7.7% of body weight.

B. **Bischoff's Method :** The Welcker's method was also employed upon decapitated criminals in order to obtain a value for the blood volume in man, but since its applicability was obviously very limited, indirect methods were later devised.

II. Indirect Method (In Man) :

A. Plasma Volume Determination :

(a) **Dyestuff Method** : The dye method was originally devised by *Keith, Rowntree* and *Geraghty*. The dyes which are used are the Congo red or Blue azo-dye T-1824 (Evans Blue). Here Congo red dye method is described as follows :

Principle : The dyestuff method depends on the introduction into the circulation of a known amount of a non-toxic dye which remains in the circulation long enough to become thoroughly mixed with the plasma ; its concentrations is determined colometrically. From the extent of the dilution the plasma volume may be calculated.

Procedure : (1) 500 mg. of Congo red are dissolved in 25 ml. of sterilized saline prepared with doubly distilled water to avoid the occurrence of ill effects such as rigors. (2) 5 ml. of blood i.e., sample A are removed from an arm vein and transferred to an oxalated haematocrit tube. (3) 10 to 15 ml. of the congo red solution are injected through the same needle. (4) After 4 minutes another 5 ml. of blood i.e. sample B are removed and placed in another tube, (5) The tubes are spun until the volume of the corpuscular sediment is constant, the ratio of cell to plasma volume is read off. (6) A standard solution containing a known strength of the dye is prepared. Sample B is matched against the solution in a colorimeter. (7) The degree of dilution of the dye in the plasma volume can be calculated.

Results ; Volume of dye injected = 15 ml.
Dilution of dye in plasma = $\frac{1}{200}$
∴ Plasma Volume = 15×200 ml.
= 3000 ml.

(b) **Radio-Iodine-Protein Method** :

Procedure : (1) 5 mg. of iodine containing a trace of radioactive isotope either I^{132} or I^{131} are added to 50 ml. of plasma in vitro ; the iodine combines with the plasma protein. (2) The treated plasma is injected intravenously ; the degree of dilution of its radioactivity is a measure of plasma volume. (3) 10 to 25% of the iodinated protein does escape from the plasma within the first hour after injection.

Results : The plasma volume so determined is 2·8 to 3·0 litres in men and 2·4 litres in women.

B. Red Cell Volume Determination :

(a) **Plasma volume and Haematocrit method** :

Procedure ; (1) The relative volume of plasma and corpuscles is determined by centrifuging heparinized blood in a graduated haematocrit tube (2) The volume of packed red cells which sediment below the plasma is measured.

Results : Usually there are 45 ml. red cells and 55 ml. plasma in

100 ml. of blood. Hence if the plasma volume is 2750 ml. and the haematocrit ratio is 45/55 the cell volume is 2250.

∴ The total blood volume
=Plasma volume+Red cell volume
=2750 ml +2250 ml.
=5000 ml. or, 5 litres.

(b) **Radio-active Iodine Serum Albumin method :**

Fractionated albumin from serum is incubated with radio active iodine. Then the radio-activity of subject's blood is estimated as dilution method.

Q. 22. Describe the Regulation of Blood Volume :

According to Starling's hypothesis, there is a continuous interchange between blood and extra-cellular fluid, so that the relative volumes of these two fluid compartments represent a steady-state, any disturbance of which will lead to the increase of the one at the expense of the other. Since, as we shall see, the maintenance of a fairly constant total volume of circulating blood is important from the dynamic aspect of maintaining a regular circulation, the study of this interrelationship is of great physiological importance.

I. Plasma Volume Regulation :

(a) Role of Physical factors :

(1) **Homeostasis :** The blood plasma and extra-cellular fluid may be regarded as having an inherent tendency to homeostasis, in the sense that an increase in the one compartment usually creates conditions that lead to a restraint on this increase.

(2) **Capillary pressure :** The effect of an increase in capillary pressure is partly compensated by the increased difference of osmotic pressure created by the extra filtration.

(3) **Effects of drinking water :** The intake of a large quantity of water causes a dilution of the plasma proteins that reduces the colloid osmotic pressure and more fluid is filtered into the tissue spaces causing little effect on blood volume.

(4) **Intravenous saline :** The intravenous injection of isotonic saline dilutes the plasma proteins and produces transitory increase of blood volume.

(5) **Plasma substitutes :** Injection of a concentrated solution of plasma proteins such as dextrans may permanently increase the difference of osmotic pressure between plasma and extra-cellular fluid.

(6) **Haemorrhage :** In severe haemorrhage, the capillary pressure fall and filtration tendency decrease while reabsorptive tendency increases.

(7) **Capillary Permeability :** The constancy of the volume of circulating fluid if the loss of the impermeability of the capillary membrane to proteins.

(8) **Tissue Spaces** : Any increase in the blood volume will lead to passage of more fluid from the plasma to the tissue spaces, while any decrease, it will draw in more fluid from the tissue spaces and maintain the blood volume.

(b) **Role of Endocrine Glands** :

(1) **Antidiuretic hormone of Posterior Pituitary** : This hormone controls excretion of water through the kidneys. When blood is diluted the secretion of antidiuretic hormone is inhibited and thus more water is lost. When blood becomes concentrated, reverse changes occur.

(2) **Parathormone of Parathyroid gland** : This hormone, by its effects on calcium metabolism controls the permeability of the blood vessels and thereby regulate the rate of interchange between blood and tissues.

(3) **Mineralo-corticoid hormone of Adrental Corex** : The desoxy-corticosterone hormone causes retension of salts and as a consequence a rise in plasma volume.

(c) **Role of Vitamins** :

(1) **Niacin or Pellegra-Preventing factor** : It is one of the vitamin of B-Complex Group, takes part in the regulation of plasma volume by controlling the permeability of the capillaries.

(2) **Anti-scorbutic factor or Vitamin C** : It is a water soluble vitamin by controlling the permeability of the capillaries takes part in the regulation of plasma volume.

II. Cell Volume Reulation :

(a) **In Physioloical Conditions** :

(1) The number of red cells are increased by high altitude such as inhabitants of mountaineous regions, muscular exercise and emotional state, high environmental temperature and low oxygen tension in the arterial blood. (2) The number of red cells are reduced by high barometric pressure and living in deep mines.

(b) **In Clinical Conditions** :

(1) The red ced volume is increased in polycythaemia vera, thyrotoxicosis or hyperthyroidism and leukaemia etc. (2) The red cell volume is decreased in pernicious anaemia, repeated small haemorrhages, chronic carbon dioxide poisoning etc.

Q. 23 What is Blood Group ? Describe the different type of blood groups.

The transfusion or intravenous injection of citrated blood led to some diastrous results and investigation revelated that there was something as incompatibility even amongst of the subjects of the same species. It was obcourse known that such incompatibilities do exist among the animals of different species. Thus human blood corpuscles will at once agglutinate in horse serum. This agglutination was caused by specific contituents of the plasma (agglutinin) of one individual reacting with a specific receptor of the red blood corpuscles (agglutiongen) of the other.

Different Types of Blood Groups :

I. **A, B and O Groups :** This type of blood group system was discovered at first and remains the most important in transfusion practice.

Observation has shown that all individuals, without distinction of age or sex, can, as regard, blood-asglutination, be included in four groups. According to *Landsteiner*, persons are classified accordingly as O, A, B and AB group. The plasma of group A contains an agglutinin β which reacts with agglutinogen B. The plasma of B contains an agglulinin α which reacts with agglutiongen A. The plasma of group O contains an agglutinin αβ reacting with agglutinogen A and B. The plasma of AB has no agglutinin and produces no clumping of the corpuscles of any group.

For practical purpose we can ignore tha Donor's serum. Since it is very much diluted by the blood of the Recipient upon the cells of the donor when the donor belongs to **Group O** and therefore his blood may be transfused to the blood of any person. As there is no agglutinogen, no agglutination will occur and so the person belonging to group O are called **Universal Donor.** The persons belonging to Group AB possess on agglutinin in their serum and so they are called **Universal Recipients.** Studying from the above facts the red cells and plasma of the four blood groups are summarised in the following table :

DONOR or Corpuscle Groups	RECIPIENT or Plasma Groups				% of Individual in each Group
	α(B)	β(A)	O (AB)	αβ (O)	
A (β)	+	–	–	+	40%
B (α)	–	+	–	+	10%
AB (O)	+	+	–	+	7%
O (αβ)	–	–	–	–	48%

'+' means agglutination (i.e. incompatible) and '–' means no agglutination (i.e. compatible).

II, **Rhesus (Rh) Factor :** The red blood cell not only contains the agglutinogen, A and B but also contains other agglutinogen, one of which is present in 85% of the human red blood cells. It is so called because it is present in the R.B.C. of the species of Rheseus monkey. This Resus factor is positive in 85% cases and negative in 15% cases. If we inject the blood of Rhesus Positive to the blood of Rhesus Negative, 12 days after, the agglutinin in the blood serum of the recipient, known as Anti-RhesusAgglutinin. So Rhesus Factor causes the appearance of this agglutinin. Rhesus Factor is injected into the blood of one person and if it is again injected for second time after 12 days or a fortnight after the first injection, then there will be hæmolysis atter 12 days due to the presence of anti-aggliutinin which causes agglutination of R.B.C. of Rhesus foctor.

III. **M, N, and MN Factors:** According to *Landsteiner* and *Levine* in 1928, that the antigens M and N were first discovered by injecting human red cells into rabbits, absorbing the resulting immune serum with one sample of human cells and showing that it would still react with other samples. These groups are of no imrortance for blood transfusion but are of value of paternity tests. The frequencies of the different MN groups are shown below :

Genotype	Phenotype	Reaction with		Frequency %
		anti − M	anti − N	
MM	M	+	−	28
MN	MN	+	+	50
NN	N	−	+	22

IV. **The Lutheran (LU) System:** About 8% of the English population belong to this system. The anti-LU anti-body was found in a woman who had never been transfused but had three previous pregancies.

V. **The Diego (Di) System:** The antibody revealing the existence of the antigen was found in a woman whose infant was affected with hæmolytic disease of the new born and the family was of mixed negative Venzuelan and White race.

VI. **The Sutter (Js) System:** The anti-body of this system in man was found in a young white male adult. According to *Giblett* and *Chase* in 1959, the patient had received a transfusion 10 months previously of blood from two donors, one of whom was a negro. The antigen was found to be present in the blood of 20% of negroes but was not present in any of 500 samples from white donors.

Q. 24. What is Blood Transfusion ? Describe the indications, routes, teachnique and precautions necessary in blood transfusion.

Blood is an extremely valuable and life saving fluid but it is a potentially lethal fluid. The intravenous administoation of Donor's blood to the recipient in known as blood transfusion. Simple precautions taken before and after its use will reduce some of the hazzards, prompt action may limit or resume the effects of these hazzards if they occur. The use of balanced salt solution with blood transfusion increases its effectiveness and reduce the total volume of blood needed at transfusion.

Indications for Blood Transousion ; The various types of indications for transfusion of blood are the following : (1) *Acute Haemorrhage* : In this case, loss of 1500 ml. or more blood results in fall of blood pressure, reduced cardiac output, increased pulse rate because in such conditions, normal circulation cannot be maintained by reflex vasoconstriction. (2) *Oligaemia* due to plasma loss. The common causes are after burning, obstruction of small intestine and some crush injuries. (3) If the *gaemoylobin concentration* is less than 10 gms% before a major operation because low concentration delays healing (4) In case of normal *jaundice*. (5) *In snake bite*. (6) *Anaemias* due to predominantly to under production of red cells—such as aplastic-anaemia, various types of leukaemia and anaemias associated with chronic nephritis, hepatic cirrhosis and severe chronic infections, (7) *Haemolytic anaemias* due to the production of 'faulty' red cells and a destructive process of removal of red cells from the blood stream in a randam fashion. (8) In *Chronic leukaemia* with splenomegaly and in acute leukaemia. (9) Anaemia produced as a result of *recurrent haemorrhage*. (10) Pre-operative transfusion. (11) Anaemia in pregnancy. (12) Post partum anaemia due to loss of blood during delivery. (13) Transfusion for a degree of Anaemia endangering life.

Routes for Transfusion : There are a number of routes of blood transfusion which are : (1) Intravenous transfusion, (2) Intraperitoneal transfusion. (3) Re transfusion of blood obtained from the peritoneal cavity. (4) Intrasternal transfusion. (5) Intramuscular and sub-cutaneous transfusions,

Technique of Blood Transfusion : The technique of blood transfusion comprises about the collection of blood, storage and administration of blood.

(*a*) **Collection of Blood** : The donor lies on a table and a rubber tube or the cuff of a sphygmomanometer is applied round the arm and inflatted to about 70 m.m, Blood is taken from the antecubital vein and collects into a bottle containing 3·8% sodium citrate solution (80 ml. for 1 pint)

(*b*) **Storage of Blood** : If the blood is not transfused immediately, it can be stored in a refrigerator at a temperature of 2° to 6°C but must be used within 14 to 21 days. The stored blood separates out into two layers—corpuscular layer sinks to the bottom and the supernatant plasma shows as a yellowish fluid. After a varying period of storage, the fragility of the red cells increases and partial heamolysis occurs with diffusion of the corpuscular pigment upwards into the plasma layer. A zone of haemolysis more than one inch is incompatible ; the blood in such cases should be discarded.

(*c*) **Administration of Blood** : This is done usually by the drip method. The rate of transfusion varies according to necessity. A shocked patient can safely be given 2 pints in 5 minutes. As a rule, enough blood should be transfused to raise the systolic pressure to 100 m.m. Hg.

In children whose veins are too small, *marrow transfusion* can be employed. The sternum or the tibia is pierced with a special trocar and cannula, directed upwards, until sudden loss of resistance indicates that the marrow cavity is reached.

Precautions necessary in Blood Transfusion.

(1) The donor must be healthy and must not suffer from any diseases like malaria, tuberculosis and syphilis. (2) The transfused blood must not coagulate before transfusion and for this anticoagulant such as sodium citrate solution is used. (3) The transfused blood must be very slow and 100 to 200 ml. of blood is tranfussed per hour. When large amount of blood is transfussed, the right side of the heart may increase in size and thereby produce heart failure. (5) The donors' blood must be compatible with the recepient's blood and for this blood group is considered.

Q. 25. Describe the Origin, Varieties, Properties and Functions of Reticulo-Endothelial System.

The reticulo-endothelial system comprises of histocytes or macrophages which are phagacytic in nature and engulfs all sorts of foreign particles. They circulate freely in the blood and lymph.

Origin : The reticulo-endothelial system is originated from the following sources : (1) From the endothelium of the mesenchyme of the yolk sac. (2) From haemocytoblast of the general mesenchyme cells in the body.

Varieties : The cells of the R. E. system may be broadly divided into two large groups viz., fixed R. E. cells and wandering R. E. cells.

I. **Fixed Reticulo-Endothelial cells :** It includes the following varieties :

(1) **Resting wandering cells** (Common connectiye tissue histocytes) : They are found in the loose tissue of the serous membrane of the omentum and pleura. They are round or spindle shaped and under suitable stimulus they may be free and wander through the tissue.

(2) **Reticulum cells** : They are found in the reticulum of the spleen, lymph gland and bone-marrow and lie among and attached to the fibres of the reticular stroma. These are large cells joined to one

another by means of long branching processes under necessary stimulus they may become detached and actively motile.

(3) **Endothelial cells :** They are present in the lining membrane of blood sinuses of the spleen, bone-marrow, adrenal cortex, liver and pituitary gland. One large flattened stellate cells of kupffer occupy the blood sinuses of the liver.

(4) **Microglia :** These are small cells and occunpy in the central nervous system.

II. **Wandering Reticulo-Endothelial cells :** They include the following varieties

(1) **Wandering histocytes :** They are found in the splenic pulp, lymph gland, omentum, bone-marrow and in the general connective tissue. They are very large in size and may come to rest which become fixed for the time.

(2) **Wandering histocytes of blood :** They are of two varieties :

(i) **Normal monocytes of blood** which are present in the blood stream. They arise from histocytes specially of the spleen and bone-marrow or macrophages may be transformed into monocytes.

(ii) **Abnormal foreign cells** are generally remain in spleen and bone marrow and into the venous blood under different pathological conditions like Leukaemia, Bacterial endocarditis etc.

Properties of the R. E. System : (1) The histocytes are stained in the living state by weak solution of certain colloidal vital dyes like pyrrol-blue, litheium carmine etc. (2) They are generally occupy the endothelial lining and reticular spaces of the connective tissues. (3) They can take up suspended particles like carbon, quart etc. when introduced in the blood stream. (4) They also can take up lipoid matter when introduced into the blood stream. (5) These cells are endowed with remarkable powers of altering their shape, size, mode of living and thereby undergo differentiation into other types of tissue cells.

Functions of the R. E. System : (1) They have a special tendency to engulf micro-organism and may in this way serve as a protection against invasion. (2) They are regard as playing an impotant role in the reaction of tissues in tuberculosis, (3) The kupffer cells of liver and macrophages of the spleen engulf and destroy the senile red cells and white cells. (4) The monocytes and other forms of leucocytes are derived from R. E. cells, (5) R. E. cells manufacture bile pigment like bilirubin from haemoglobin. (6) Large amount of lipoids, cholesterol and iron are stored in R. E. cells. (7) The R. E. cells help in the manufacture of red blood cells. (8) Serum albumin and other varieties of plasma protein are manufactured from R. E. cells to some extent.

Q. 26. Describe the Varieties, Vascular arrangement and Functions of Bone Marrow.

Bone-marrow is the cellulo-vascular tissue of pulpy consistency which is found not only in the cylindrical marrow cavities of long bones but also in the spaces of spongy substance of all bones even in the larger Haversian canals.

Varieties : The bone-marrow differs in compositions in different bones and different ages and occurs in two forms :

(a) **Red Bone-marrow** (Medulla Ossium Rubra) ; It consists of a small amount of connective tissue, blood vessels, well supplied with vaso-constrictor nerves and numerous cells, a few of which are flat cells but the great majority are spherical, uncleated cells turned Marrow Cells or Myelocytes. No lymph vessels have ever been demonstrated in the yellow or red bone marrow. Red bone-marrow is the chief seat of haemopoiesis after birth.

(b) **Yellow Bone-marrow** (Medulla Ossium Flava) : It consists of a basis of connective tissue, supparting numerous blood vessels and cells, most of which are flat cells although some are marrow cells which are predominate in red bone-marrow. It is found in the medullary cavity of long bones.

Vascular Arrangement : Nutrient arteries of bone break up into smaller branches, which lead to a network of inter-communicating sinuses. These vessels are lined by thin endothelium but when dilated have the capacity of large veins. Many of the sinusoids under normal conditions are completely collapsed and quite impermeable to blood. They can only be demonstrated when cellular elements of marrow have been destroyed. These collapsed sinusoids are the site of erythropoiesis, other vessels are widely dilated and the blood flow then is in cosequence doubtless very slow.

Functions : (1) The red bone-marrow helps in the development of red blood corpuscls and white blood cells. (2) It helps in the formation of blood platelets from megakaryocytes. (3) It serves the destruction of red cells. (4) The bone marrow is rich in R. E. cells and serves all the important functions of the R. E. system.

Q. 27. Describe a method of Examination of Bone-marrow.

The bone marrow is the cellulo-vascular tissue occupying the medullary cavities and the cancellous spaces of the long bones. It possesses different types of cells when examined under microscope.

Procedure : In animals, the bone is taken out and squeeze out a portion of the marrow after breaking the bone. Make a film preparation of it on a clean dry slide. Allow it to dry and place the slide in the tray containing a mixture of ether and alcohol for about 15-20 minutes to remove the fatty contents of the marrow.

Staining : Take out the slide, wash with water and make the film dry again. Stain with Leishman blue or Fenner's stain. Wash with water, mount with glycerine and examine under microscope. The vital staining of the living cells of the bone marrow is done by injecting suitable preparation of Fanus green and Neutral red in the circulation of living animal.

Observations : The red bone marrow consists of a net-work of reticular tissue in the meshes of which there are numerous cells of different types and blood vessels which ramify and anastomose with each other. The following are the different types of cells found in the red bone marrow :

I. Cells of Erythroid Series :

(1) *Red blood cells* : Non-nucleated.

(2) *Normoblasts* ; 7 to 10 micron in diameter, cytoplasm is reddish and the nucleus is pyknotic.

(3) *Erythroblasts* : 10 to 15 micron in diameter and cells show active mitosis. The cytoplasm shows a mixture of dual stains giving polychromatophil appearance.

(4) *Megaloblast* or *Pro-erythroblast* : 15 to 20 micron in diameter with large nucleus with deep violet cytoplasm.

II. Cells of the Myeloid Series :

(1) *Myeloblast cell* : 12 to 18 microns in diameter, large round pale blue nuleus, cytoplasm is bluish.

(2) *Myelocytes* or *Marrow cells* : 12 to 18 micron in diameter and these cells are classified according to the reaction of granules in the cytoplasm with Leishman's stain. These are nucleated and amoeboid. The myelocytes are : (i) Neutrophilic myelocytes. taking bluish stain, (ii) Eosinophilic myelocytes, (iii) Basophilic myelocytes.

(3) *Granulocytes* : These are Neutrophil, Basophil and Eosinophil.

III. Megakaryocytes or **Giant Cells :** These are big amoeboid cells, 38 to 40 microns in diameter containing an irregular ring of lobed nuclei with a number of nucleoli.

IV. Reticulum Cells and Fibres-: Syncytium, fibres can reduce silver nitrate. Hence they are called *argyrophil fibres.*

V. Few Fat Cells : These cells eppear as empty spaces.

Q. 28. Describe the Formation, Composition, Circulation and Functions of Lymph.

Lymph is the modified tissue fluid, secreted by the lymph gland, carried through lymphatic channels performing nutritive, absorbtive and defensive function. If gives nutrition to the extreme part of the extremities where blood cannot reach.

Formation of Lymph : Lymph has been formed from tissue fluid and anything that increases the amount of tissue fluid, will increase the rate of lymph formation.

Factors Necessary for Lymph Formation :

(a) **Increased Capillary Pressure** : *Landis* and *Gibbon* found that in man, filtration from the capillaries showed a definite increase when the venous pressure raise above 12 or 15 cm, of water. Increased pressure in the veins of the portal area causes increased filtration into tho tissues of the abdominal viscera and a great increase in the volume of lymph flowing along the thoracic duct.

(b) **Increased Permeability of the Capillary wall** :

(1) **Rise in Temperature** : It increases capilary permeablility. raises the filtration rate and the flow of lymph has been increased.

(2) **Capillary Poisons** : (i) **Peptone** increases the flow of lymph from the thoracic duct probably as a result of its injurious effect upon the abdominal capillaries. (ii) **Lymphagogues of the first class of Heidenhain** are the extracts of straw berries, crayfish, muscles, leeches, histamins and foreign protein stimulate the quick formation of lymph. (iii) **Reduced Oxygen supply** to the tissues act probably through damage to the capillary endothelium.

(c) **Lymphagogues of the Second Class** :

(1) **Hypertonic Solutions** : The intravenous injection of a concentrated solution of glucose, sodium sulphate or sodium chloride causes an increase flow of lymph from the thoracic duct.

(2) **Isotonic Normal Saline solution** : This injection will also increase the lymph flow since the plasma colloids are diluted and thereby the filtration through the capillary is increased.

(d) **Increased Functional Activity** : (1) Formation of metabolites which increase the osmotic pressure of the tissue fluids and so attract more fluid from the vessels. (2) Vasodilatation and increased capillary pressure. (3) The contracting muscles exert a pumping effect upon the lymph, during it along the vessels.

(e) **Massage and Passive Movement** : It acts to a certain extent like muscular activity. They augment the blood flow and capillary pressure and so increase lymph formation.

Composition of Lymph :

The major difference in composition of plasma, interstitial fluid and lymph is the protein concentration. The protein concentration of plasma is about 7%. In interstitial fluid, it varies from about 0.3% on upto about 3%. The concentration of protein in lymph reflects than in the interstitial fluid. Lymph collected from the thoracic duct usually contains about 3% protein.

I. Physical Properties :

(a) **Colour :** (1) **During fasting :** It is transparent and yellowish in colour. (2) **After fatty food intake :** It is milky white due to minute droplet of emulsified fat absorbed from alimentary canal.

(b) **Colloidal Osmotic Pressure :** It is lower than that of plasma and higher than that of tissue fluid,

(c) **Reaction :** It is alkaline in reaction.

(d) **Specific gravity :** It is about 1015.

II. Chemical Composition :

A. **Water :** 94%

B. **Solids.** 6%

(a) **Cellular Part :** (1) Leucocytes—1,000 to 20,000 per cu. m.m. (2) Erythrocytes—3,000 to 13,000 per cu.m m.

(b) **Non-Cellular Part :** (1) Proteins—3·32%(2) Fat—5 to 15% (3) Carbohydrate—132·2 mg.% (4) Other Constituents :

(i) Urea—23·5 mg. (ii) Non-Protein Nitrogen—34·8 mg. (iii) Creatinine—1·4 mg (iv) Chlorides—711 mg. (v) Total Phosphorous—11·8 mg. (vi) Inorganic Phosphorous—5·9 mg. (vii) Calcium —9·84 mg.

Circulation of Lymph : The lymph from right forelimb, right head, neck and chest region is drained into the superior vena cava via right lymphatic duct and right subclavian vein. The lymph from hind limbs of right and left side, alimentary canal, abdominal and pelvic region is drained into the thoracic duct via receptaculum chyli. The thoracic duct also receives lymph from left fore limb and left head, neck and chest region. The lymph of the thoracic duct drains into the left subclavian vein then into superior vena cava. All the lymph materials of the superior vena cava are finally drained into the right atrium of the heart.

Factors maintaining circulation of Lymph :

The circulation of lymph has been maintained by following factors :

(a) **Rate of Flow :** The rate of flow along the human thoracic duct is from 1 to 15 ml. per minute. *Cain* and his associates found an average flow of 3·46 ml. per minute in the thoracic duct, of which more than half, about 0·26 ml. was contributed by the lymph vessels of liver.

(b) **Pressure Gradient :** Under ordinary conditions the pressure of the thoracic duct content is about 15 c.m. of water. The pressure in the peripheral lymph vessels during rest, run from 0 to 6 c.m. of water.

(c) **Presence of Valves :** The presence of valves in the lymphatic channels help to maintain the flow of lymph in one direction.

(d) **Muscular Action :** It may be active or passive which compresses the lymphatic vessels and help to flow the lymph from cisterna chyli to the thoracic duct.

(e) **Respiratory Movement** : During inspiration, intra-thoracic pressure falls but intra-abdominal pressure rises which compresses the cisterna chyli and flow the lymph in the thoracic duct has been increased.

Functions of Lymph :

(a) **Nutritive :** It supplies as a form of oxygen via blood to those parts where blood cannot reach.

(b) **Drainage** : It drains many excess tissue fluids and the metabolites and thereby constant volume and composition of tissue fluid is maintained.

(c) **Absorption of Fat** : Fats from the intestine are absorbed mainly through the lymphatic channel via lacteals.

(d) **Defensive Function** : The lymphocytes and monocytes of lymph acts as a defensive cells of the body. The lymph nodes seem to be responsible for the formation of gamma-globulin and specific antibodies to assist in combating infection.

Q. 29. Describe the Formation, Composition, Drainage and Functions of Tissue Fluid.

Tissue fluid occupies the intercellular space and forms the connecting link in the transport of nutrition, gases and the metabolic end products between blood capillaries, the tissue cells and the lymph. It constitutes the internal enviornment of the body which surrounds the tissue cells.

Formation of Tissue Fluid : Tissue fluid is formed from two sources—Blood capillaries and Tissue activities.

(a) **From Blood Capillaries** : Tissue fluid is derived from blood capillaries which depends upon (i) Capillary permeability. (ii) Difference of pressure between the capillary and tissue fluid. (iii) Difference of colloidal osmotic pressure and tissue fluid.

(b) **Tissue Activities** : (i) During activity, large non-osmotic molecules of the resting organ break down into numerous smaller molecules which pass into the tissue spaces. (ii) The blood-flow through the active organ is very great and so fresh supplies of fluid are canstantly available to make up for the fluid lost to the tissues. (iii) The capillaries in the active region become widely dilated and those previously closed open up, the capillary membrane becomes thinner and more permeable, permitting more rapid diffusion.

Conditions which increase the Tissue Fluid Formation ; The factors that increasing the tissue fluid formation are the following :
(a) Increase in capillary pressure as a result of venous obstruction.
(b) Increased permeability of the capillary wall which depends upon :

(i) A rise of temperature. (ii) Capillary poisons. (iii) Reduced oxygen supply. (iv) Hypertonic solutions. (c) Isotonic solution. (d) Increased functional activity which depends upon : (1) Formation of metabolites. (2) Vasodilatation and increased capillary pressure. (e) Massage and Passive movement.

Composition of Tissue Fluid : The composition of tissue fluid is same as that of lymph except the protein is nigligible and thereby its colloidal osmotic pressure is very low *Stead* and *Warren* in 1944, collected tissue fluid by placing fine hypodermic needles in the subcutaneous tissue and obtained minute quantities of a yellowish fluid with a high protein concentration. In venous congestion, a small amount of clear fluid were obtained with a mean concentration of 0·8% protein. In abnormal subjects with cardiac and hepatic oedema, the protein concentration of the tissue fluid becomes 0·24%.

Drainage of Tissue Fluid : The removal of tissue fluid are done by the following means : (1) It is retained in the tissue spaces. (2) It escapes into the lymphatics. This may be the purpose of the lymphatics in the normal body in the absence of infection. (3) In case of glands, it is mainly poured out in the external secretion. When the tissue comes finally to rest the metabolities either diffuse into the blood or are oxidized, and thus the osmotic pressure of the tissue spaces falls.

Functions of Tissue Fluid : The functions of the tissue fluid are : (1) It constitutes the internal medium in which the tissue cell are bathed and supplies nourishment for them and excretes their metabolites. (2) It acts as a great reservior of water, salts, nutrition, etc. (3) It maintains plasma volume.

Q. 30. Write short Notes on :—

(1) **Haemoglobin :** Haemoglobin is a conjugated protein or chromoprotein present in the red blood cells. It consists of basic protein globin (histone) united with four prosthetic haem groups. Haemoglobin is the red pigment which gives blood its characteristic colour. There are two types of compounds of haemoglobin known as stable and unstable compounds. The stable compounds are carboxy-haemoglobin, Nitric oxide haemoglobin, Nitroxy haemoglobin, etc. and the unstable compounds are carbohaemoglobin, sulph-haemoglobin, oxyhaemoglobin etc. The derivatives of haemoglobin are the iron containing and iron free derivatives. The iron containing derivatives are Haematin, Haemochromogen, Haemin, Cytochrome, Methaemoglobin, Cyanmethaemoglobin, etc. The iron-free derivatives are the Haematoporphyrin, Haemopyrrol, Haematoidin, Bilirubin, Urobilin, Stercobilin. etc.

(2) **Haemolysis (Fragility) :** Haemolysis is a process in which the haemoglobin content of red blood cells is discharged in the surrounding fluid when red blood cells are introduced in a hypotonic solution. **Factors causing Haemolysis :** The different factors that cuse haemolysis are : (i) Simple dilution of blood. (ii) Various

chemical substances like chloroform, benzene, bile salt, ether, etc. (iii) Bacterial and parasitic toxins, (iv) Haemolysins in blood serum. (v) Hypotonic saline, etc.

(3) **E.S.R.** : (Erythrocyte Sedimentation Rate) : If blood is kept fluid by anti-coagulant is allowed to stand in a narrow tube, the corpuscles settle progressively to the bottom while plasma rises to the top. The rate at which this takes place is very constant in health and is known as Sedimentation Rate of Erythrocytes or E.S.R. or Suspension stability of Blood. The normal E.S.R. varies as follows : (i) It is lowest in new born baby i.e. 0·5 m.m. per hour. (ii) For a healthy male, it is 2 to 3 m.m. per hour. (iii) For a healthy female, it is 3 to 7 m.m. per hour. (iv) In pregnancy, the E.S.R. increases.

(4) **Polyerythaemia :** The red cell count is increased due to chronic anoexia, in excess loss of fluid (dehydration), in histamin shock and in some forms of traumatic shock from primary over-action of red bone narrow and in congenital heart diseases.

(5) **Purpura** : When the platelet count falls, it will cause capillary bleeding and the individual possesses a purple spots over the skin which will produce the disease known as *purpura*.

(6) **Castle's Haematinic Principle :** The haematinic principle is formed in the stomach and passes into the small intestine Then it is absorbed into the portal blood and ultimately reaches into the liver where it is stored. It is formed by the combination of two factors known as *Extrinsic factor* and *Intrinsic factor* The extrinsic factor is present in rice polishing, meat, yeast cells and yeast extracts, Vitamin B_{12}. The intrinsic factor is an enzyne present in the gastric juice and is secreted by the cells of the fundus of the stomach. The extrinsic factor modifies it or interacts with it so as to promote its absorption from the intestine. The haematinic principle passes from the liver to bone narrow by the blood stream and helps in the conversion of megaloblast into early erythroblast stage.

(7) **Oedema** : It is an abnormal excessive accumulation of fluid in the intercellular tissue spaces due to the disturbance in the mechanisms of fluid interchange in the body.

(8) **Elephantiasis** : It is a condition of swelling of the extremities of the body duo to the blockage of the lymphatic duct from a limb. There will be high concentration of protein i.e. 2 to 3·5% in the extra-cellular fluid.

CHAPTER SEVEN

CIRCULATORY SYSTEM

Indroduction : The circulatory system comprises of heart, blood vessels and blood. The heart is the central pumping station, situated in the thoracic cavity, made up of half artery and half vein, consists of a receiving chamber or atrium which receives deoxygenated blood from the veins and a delivering or forwarding chamber or ventricle which propels the oxygenated blood into the arterises.

The heart is covered by pericardium and the structure is made up of serous epicerdium, muscular myocardium and mucous endocardium. The special junctional tissue of the heart is situated within the muscular layer. The heart consists of two atria and two ventricles separated by artio-ventricular septum. The two artia are separated by inter-artial septum and the two ventricles are separated by interventricular septum. The valves of the heart are bicuspid or miral valve, tricuspid valve, aortic valve, pulmonary valve, etc.

The blood vessels are generally the arteries and veins which are connected by capillaries. The vessels have got three layers known as tunica adventitia, tunica media and tunica intema.

The content of the heart and blood vessels is blood which is a red coloured fluid. It is composed of liquid plasma and cellular elements like erythrocytes or red blood cells, leucocytes or white blood cells and platelets or thrombocytes.

Q. 1. Describe the structure of Heart and discuss the different types of circulation through heart.

The heart is a central pumping station of the body. It is a hollow muscular organ and made up of half artery and half vein. Each half of the heart consists of a receiving chamber or artium which receives deoxygenated blood from the veins and a delivering or forwarding chamber or ventricle which propels the oxygenated blood into the arteries.

Physiologic Anatomy : The heart consists of two *artia* and two *ventricles* separated by artio-ventricular septum. The two artia are separated by *inter-artial septum* and the two ventricles are separated by *interventricular septum.* A conical pouch-like projection from both atria, which embraces the great vessels of the heart is called the corresponding *auricle of the heart* i.e., from the right artium the right auricle and from the left artium the left auricle. The *aorta* (ascending aorta, arch of aorta and descending aorta) arises from the left ventricle and carries oxygenated blood to the different parts of the tissue for supplying nutrition. The *pulmoary artery* arises from the right ventricle and carries deoxygenated blood to the lung for purification of blood. The right artium receives all the deoxygenated blood from the body through ***Inferrior vena cava, Superior vena cava*** and ***Coronary***

sinus. The left artium receives all the oxygenated blood from the lungs through *pulmonary veins.* The features within the right artium are *crista terminals*, a smooth muscular ridge and *musculae pectinati* which is a series of numerous parallel muscular ridges. The features within the right ventricle are *Right atrio-ventricular orifice*, *Pulmanary orifice*, *Tricuspid valves*, *Pulmonary valves*, *Trabeculae carneae*, *Moderator bands* and *Infundibulo-ventricular crest.* The features within the left atrium are *Openings to the pulmonary veins*, *Left atiio-ventricular orifice*, *Foramina venarum minimarum* and *Musculae pectinati.* The features within the left ventricle are *Left artio-ventricular orifice*, *Aortic orifice*, *Bicuspid* or *Mitral valve*, *Aortic valves*, *Trabeculae carneae* and *Chordae tendineae.*

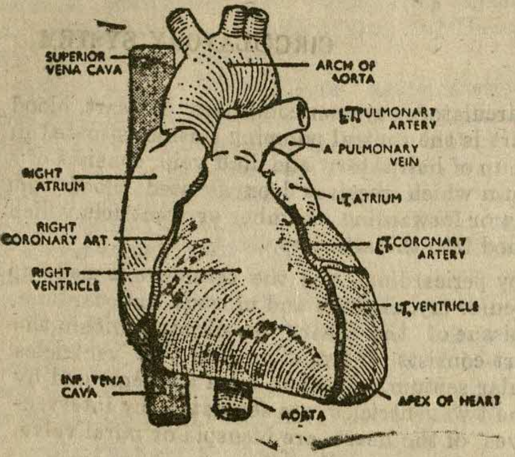


Fig. 8. Diagrammatic representation of the Heart showing its different chambers, valves and vessels.

Physiologic Histology: The heart is composed of an outer serous pericardium known as *Epicardium*, an inner endothelial lining known as the *Endocardium* and an intermediate

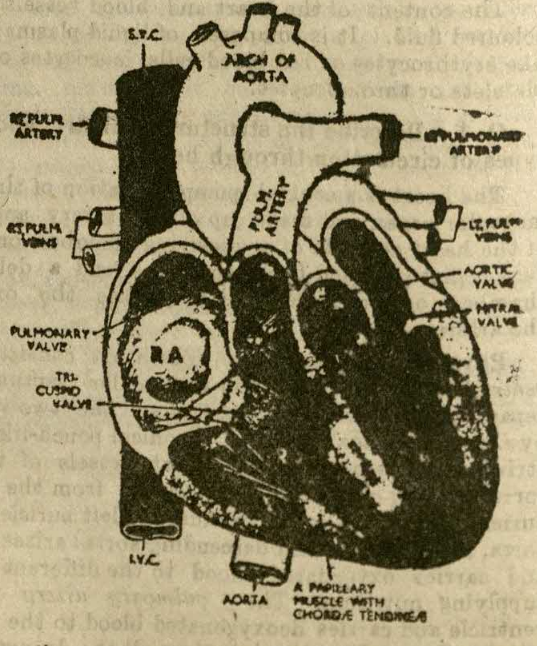


Fig. 9. Diagrammatic representation of the Heart showing its different structures present in the atrium and ventricle.

muscular layer lying in between the epicardium and the endocardium known as the *Myocardium*. The atrium is composed of three types of muscular fibres known as superficial transverse fibres, deep looped fibres and annular fibres. The ventricles consist of superficial spirally arranged looped fibres and deep fibres of eight figure. The atrio-ventricular orifices, the pulmonary and aortic orifices, are surrounded each by fibrous band known as the trigonum fibrosum dextrum and it is connected with a similar band of fibres to the pulmonary ring known as the tendon of the infundibulum.

Different Types of Circulation through Heart : The circulation of blood through heart are grouped into two categories. These are general circulation and regional ciculation.

I, **General Circulation :** The general circulation of blood through heart is done by the pumping action of the cardiac musculature and thereby oxygenated blood goes into the different parts of the body and the deoxygenated blood goes into the lungs for further purification. The general circulation constitutes *Systemic circulation* and *Pulmonary circulation*.

(a) **Systemic Circulation** (Greater Circulation) : The left ventricle receives oxygenated blood from the left atrium through left atrio-ventricular orifice guarded by bicuspid or the mitral valve. From the left ventricle, aorta runs forward and then bends on the left to form the *arch of aorta*. The arch of aorta gives rise to *Innominate artery*, *Left common carotid artery* and *Left subclavian artery*. The carotid artery divides at the angle of the jaw into the *internal carotid artery* which supplies the brain and the *external carotid artery* which supplies the face. The subclavian artery gives out branches called the *brachial artery* supplying the forelimb, *internal mammary artery* and the *intercosartal artery* supplying the chest. The arch of aorta curves downward into the thorax and gives out a number of paired *intercostal arteries*. On reaching the abdomen, the abdominal aorta gives off a large *coeliac rtery*, which sub-divides into *hepatic artery* supplying the liver and a *lineogastric artery* supplying the stomach and the spleen. The aorta gives out an another branch known as *anterior mesentric artery* which supplies the intestine and pancreas. The aorta gives a branch of *renal artery* which supplies the kidney. It gives branch of *spermatic artery* that supplies testis and *ovarian arteries* for supplying ovaries. The main descending aorta divides into two branches at the level of the pelvic region into two *common iliac arteries*. The common iliac artery supplying the pelvic region divides into the *internal iliac* and the *external iliac* which gives off the femoral artery supplying the leg.

The veins returning blood from the face, forelimbs, head and neck through *Superior vanacava*. The veins returning blood from the hind limb, pelvis, abdomen, thoracic region and different abdominal, thoracic and pelvic visceras through *Inferior venacava*. The two venae cavae open into the right atrium of the heart.

(b) **Pulmonary Circulation** (Lesser Circulation): The right ventricle receives deoxygenated blood from the right artium. The deoxygenated blood goes to the lungs from the ventricle through pulmonary artery and purification of blood takes place in the lungs by gaseous exchange mechanism. When deoxygenated blood is purified, the purified, blood then returns to the left artium through pulmonary veins. From left atrium, the oxygenated blood goes into the left ventricle and from there, it goes into the different parts af the body through systemic circulation.

II. **Regional Circulation :** The circulation in a particular region or organ is done by the blood flow from the systemic circulation is known as *Regional Circulation.* This type of circulation is adjusted by regulating the general circulation and the local blood vessels. By this mechanism, blood is shifted from the inactive to the active regions without any disturbance of general circulation. The various types of regional circulation are discussed as follows :

(1) **Coronary Circulation :** This type of circulation helps to give the blood supply of the musculature of the heart. The *arterial supply* is mainly done by the right and left coronary arteries arising from the root of the aorta. The *venous drainage* is served by superficial and deep venous system. The superficial venous system constitutes the coronary sinus, great cardiac vein and anterior cardiac veins. The deep venous system consists of Thebesian, luminal and sinusoidal vessels.

(2) **Cerebral Circulation :** This type of circulation helps to give the blood supply of the different parts of the brain. The *arterial blood supply* is done by the two internal carotid arteries, two vertebral arteries and the circle of Willis. The *venous blood* drains into large cerebral sinuses like the superior sagittal, inferior sagittal, cavernous, straight, etc. and all of them ultimately unite to form two transverse sinuses which become continuous with the two internal jugular veins.

(3) **Pulmonary Circulation :** It helps to give blood supply to the lung tissue. The *arterial supply* of the lung is done by the pulmonary and bronchial arteries. The *venous blood* is mostly returned through bronchial veins and partly through azygos vein.

(4) **Hepatic Circulation :** It helps to give blood circulation through the liver. The *arterial system* constitutes the portal vein and hepatic artery. They have anastomotic connections with the sinusoid. The *venous blood* collects into the central vein which ultimateley drains into the inferior vena cava.

(5) **Capillary Circulation :** The capillaries are lined by a layer of flat endothelial cells surrounded by a basement membrane and bounded by an intracellular substance. The arterioles are connected with meta-arterioles that lead into throughfare channels and are connected with venules. At the root of each capillary there is a precapillary sphincter that adjusts the flow of blood but in the thoroughfare channels, there is no such sphincter and there by the flow of blood cannot be adjusted.

(6) **Splenic Circulation :** It helps to give blood supply through the spleen. The *arterial supply* is done by the splenic artery with its branches and the *venous blood* drains into the splenic vein that ultimately enters into the inferior vena cava. The splenic circulation are of two types like short and long circulation. The short circulation helps the rapid flow of blood through narrow capillaries. The long circulation has got three phases known as filling phase, storage phase and emptying phase.

(7) **Renal Circulation :** This type of circulation helps not only to give blood supply to the kidney tissue but also helps in the mechanism of urine formation. The *arterial supply* is done by the renal artery with its branches. The *venous blood* is drained by the renal vein which ultimately enter into the inferior vena cava.

Q. 2. Describe the histology of Cardiac Muscle and discus its properties.

The heart is a central pumping station, responsible for the force necessary to make the blood circulate. It is a hollow organ with muscular walls and has a system of valves so disposed that when the heart muscle contracts the blood that fills the cardiac cavities is driven forward from the venous to the arterial side. The fundamental structure and properties of the cardiac muscle fibres are of essential importance in the function of the heart.

Histotogical Structure : (1) The cardiac muscle fibres consist of quardtriangular forked cells with central nuclei and the branches of branch to branch forming a contractile net work known as cellular syncytium. (2) The sarcolemma is illdefined and intervening between the fiibres is a very thin layer of loose connective tissue. (3) The sarcoplasm is more granular and cotains myofibrillae towards the periphery of the cell where as the nuclei are placed centrally either in rows or in close packing. (4) Each of the muscle fibre is transversely marked by darkly staining bands known as the *intercalated disc* which are not straight transverse marking connected together in steps. (5) The electron microscopic structure shows that each myocardial fibre have got 300 to 700 myofibrils. (6) Capillaries are seen to enter the myocardial fibre carrying blood to the sarcoplasm, nuclei, and myofibrils. Large numbers of sarcosomes are seen scattered among the myofibrils and near the poles of the nuclei, but never within the myofibrils.

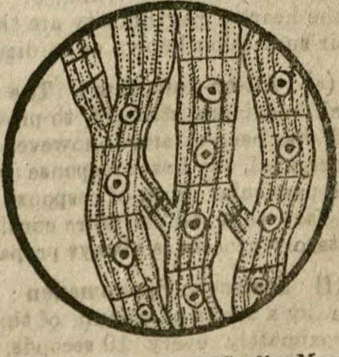


Fig. 10. Structure of Cardiac Muscle.

Properties of Cardiac Muscle : There are different fundamental properties of the cardiac muscle fibres and are discussed as follows :

(a) **Rhythmicity** : The cardiac muscle fibre has the power of originating within itself the impulse that makes it contact. As soon as the heart is formed in the embryo, before the fibres acquired their typical histological pattern it contracts rhythmically and the rhythmic beat persists when even after it has been separted from the organism.

(b) **Conductivity** : The stimulus that activates the carciac muscle has its origin in a circumscribed area but it spreads throught the heart muscle. The excitatory state is transmitted along the cardic muscle in a way similar to that by which a nerve impulse propagated along a nerve fibre. The speed of transmission of the excitatory state is dependent on the heart's conductivity.

(c) **Excitibility** : The heart has got the property of excitibility. It responses not only to the stimulus originated by its own rhythmicity, but also to external stimuli of different types like mechanical, electrical, thermal, chemical etc. Excitability incrcases rapidly very early in diastole, reaching a maximum and is maintained until next beat.

(d) **Contractility** : In response to the stimulus originated by its own rhythmicity, or to an external stimulus, the heart contracts. The muscle fibrils or myofibrils are the fundamental contractile units of the heart. The muscle after contraction forms actomyosin which is unstable in its extended or resting state and which now dissipates energy either by shortening or increased tension. Contractions due to the heart's rhythmicity are the spontaneous beats of the heart and their succession known as cardiac rhythm.

(e) **All-or-none law** : The stimulus in cardiac muscle, must also reach maximum strength to provoke a response but once the threshold has been attained, however much the strength of the stimulus is increased, the heart response with contraction of constant strength. This particular form of response observed in cardiac muscle is due to the fact that all its fibre contitute syncytium and therefore the excitatory process is always propagated throughout the whole heart.

(f) **Staircase Phenomenen** : When a heart is excited for sometime by a series of stimuli of threshold strength at rest repeatedly approximately every 10 seconds, the three or four contractions first observed are of increasing magnitude. If horizontal lines at the level of the summit of each contraction curve are traced and joined by vertical lines a staircase of three or four steps results, hence the name of "staircase phenemenon" given to this observation.

(g) **Tonicity** : Heart muscle possesses tone which is independent of nerves and can he adjusted by this process, it can maintain a fairly constant tension.

Q. 3. What are the Special Junctional Tissues of the Heart ? Describe the Origin and Conduction of Cardiac Impulse ?

There is no muscular continuity between atriums and venticles. The tendinous atrio-ventricular ring completely separate artium from venticle. Besides this, the impulse from the right atrium is regularly transmitts to the revtricle which proves that there must be a special connecting link between atrium and the ventricle that conduct impulse from one to the other. These tissue have got a special characteristic feature, situated in the special junctional region of the heart and possessing a special property about the formation and conduction of cardiac impulse which are known as special junctional tissues of the heart.

Junctional Tissues : The juoctinnal tissuses of the heart are of various types which are : (1) The Sino-Auricular node or S-A node, (2) The Auricula-Ventricular node or A-V node. (3) Bundle of His or Auriculo-Ventrcular bundle. (4) Right bundle of His, (5) Left bundle of His. (6) Purkinje fibres.

I. Sino-Auricular Node :

History : *Keith* and *Flack* discovered the sino-auricular node in 1907.

Situation : It is situated in the right atrium at the junction of superior vena cava and the right atrial appendix.

Development : It is the remnantpart of the right great vein and supplied by right vagus nerve.

Anatomy : It extends downwards along the sulcus terminalis for about $\frac{3}{4}$th. of an inch, It is broader at the top and tapering below. The average thickness being about 2 m.m.

Histology : The fibers are thin, slender, spindle shaped and longitudinal striations have seen. The fibers are arranged in a plexiform manner. In between the muscle cells many nerve cells are found which acts as a relay station of vagus and sympathetic nerve.

Function : It generates normal cardiac impulse at the average rate of 72 per minute. In the adult, it acts as a *pace-maker* of the heart.

II. Auriculo-Ventricular Node.

History : The auriculo-ventricular node is discovered by *Tawara* in 1906.

Situation : It is situated in the right atrium at the posterior part of the inter-auricular septum close to the opening of the coronary sinus.

Anatomy : It extends downward for about 2 c.m, in length. It is broader at the top and tapering below, the average thickness being about 2 m.m.

Development : It is developed from the remnant part of the left great vein and so it is supplied by left vagus nerve.

Histology : The fibers are thin, slender, spindle shaped and longitudinally striated. The fibers are arranged in a plexiform manner. In between the muscle cells many nerve cells are found which acts ae a relay station of vagus and sympathetic nerve.

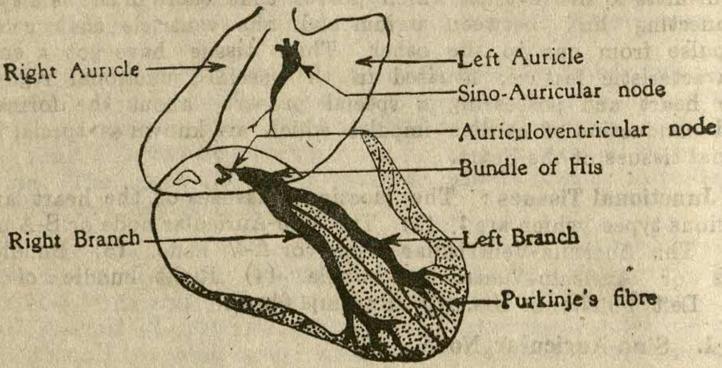


Fig. 11. Longitudinal Section of the heart showing its Special Junctional Tissues.

Functions : (1) It receives impulse originating from the S-A node and transmits to the ventricle through the bundle of His. (2) It can also initiate the cardiac impulse at a slower rate i.e. 50 per minute (3) In abnormal conditions, when S-A node fails, the A-V node generates the impulse by *rhythm*.

III. Bundle of His wiih its Branches :

Origin : The main trunk of the bundle of His arises from the auriculo-venticular node.

Course : It passes forwards along the membranous part along the interventricular septum. The bundle divides into right and left branches just above and muscular part of the septum. The left branch pierces the membranous septum entering the left ventricle and passess along the muscular septum towards the apex. The right branch passes the right side of the septum. These branches remain just under endocardium of the heart.

Structure : The bundle of His is about 1 to 2 mm. thick, consisting of fusiform parallel fibers. The fibers are broad, scanty, longitudinal striations are well marked at the periphery than at the central portion. They are rich in glycogen. The fibres gradually increased in size as are proceed onwards and merges with the Purkinje cells.

Functions : (1) Its normal function is to conduct the auricular impulse into the ventricles. (2) When S-A node and A-V node fail, the bundle of His can originate cardiac impulse at a very slow rate of about 36 per minute.

IV. Purkinje Fibers :

Origin : It originates from the right and the left bundle of His and merged with Purkinje cells of the ventricular musculature wall of the right and left ventricles.

Histology : The purkinje fibers are quadtriangular in shape, longitudinal striations are prominent at the periphery. The purkinje cells are large swollen cells with granular cytoplasm and indistinct cells membrane. They possess large and often multiple nuclei.

Origin and Propagation of Cardiac Impulse :

The impulse originated at the S-A node and spreads over the auricles like concentric waves which is received by A-V node. The S-A node is supplied by cardio-acceleratory fibre and the A-V node is supplied by cardio-inhibitory fibre both of which come from cardiac centre of medulla oblongata. These medullary cardiac centres have got a direct connection of hypothalamus and is influenced by the cortical centre of the cerebral cortex. The condition takes place through auricular musculature. A-V node transmits the impulse through the main bundle, then through its branches to the ventricles and the impulse is distributed to the corresponding points of the two ventricles at the same time.

Q. 4. "The Sino-atrial node (S-A node) is the pacemaker of the heart"—Discuss.

The sino-atrial node consists of embryonic muscle tissue. It is called as the "pacemaker" of the heart because normally the excitation wave starts from this area and then spreads to the rest of the auricle. The S-A node is the pacemaker of the heart due to following evidences :

I. **Embryological Evidence** : The cardiac impulse originates from sinus venosus in forg's heart which can proved by the stannius ligature. The sinus venosus is present in the early stage in human embryo but later it is incorporated in the right atrium. The S-A node represents a part of the incorporated sinus and it should be the "pacemaker" of the heart.

II. **Histological Evidence** : The S-A node is composed of embryonic muscle fibres which posses high excitability and thereby S-A node acts as a "pacemaker" of the heart.

III. **Experimental Evidences :** The S-A node acts as a "pacemaker" of the heart which is proved by the following experimental evidences :

(1) It has been observed that when the heart stops, it is the S-A node region which stops first.

(2) The S-A node increases the heart rate by the effect of beat and slows the heart rate by the effect of cold and no other parts of the heart reacts in the same way.

(3) The heart rate stops when S-A node is excised. The heart begins to beat at a slower rate usually appear a few minutes because A-V node takes the function of nodal rhythm of S-A node

(4) When S-A node is artificially stimulated, a normal curve with an upright P is obtained. When any other part of the auricle is stimulated, the auricle contracts but the P is inverted.

(5) In the exposed heart of a dog it was demonostrated that the S-A node region becomes electronegative first.

(6) In a case of ectopic cordis in man it was demonostrated that contraction begins in this region.

Q. 5. What do you mean by Heart Block? Describe its different varieties.

The heart block is a condition in which there is defective production of the sino-auricular impulse or its condution in the heart. There are four main types of heart block which are Sino-atrial block, Auriculo-ventricular block, Bundle branch block and Arborisation block.

Varieties of Heart Block : There are four main varieties of heart block according to site of damage.

(*a*) **Sino-Atrial Block :** The impulse is fixed to the S-A node which may fail to generate the imulse occasionally and thereby the whole heart misses one beat. The venous pulse and E. C. G. show absence of atrial and venticular complexes.

(*b*) **Auriculo-Ventricular Block :** The transmission of impulse becomes defective in the A-V node or in the main bundle of His before division. It has got partial heart block and complete heart block. (1) **Partial Heart Block** ; It may be of three types : (1) *Delayed conduction* : The impulse originates in S-A node spreads to the auricles normally, auricular impulses cannot pass throughthe ventricles within normal time due to depressed condition. The P-R interval is prolonged and is greater than 0·2 second. (ii) *Failure of an occassional beat of the auricles to reach the ventricles* : The dropped beat occurs and during the drop no heart sound is heard and no apex beat is felt. E.C.G. shows only Pwave which is unaccompanied by Q R S T wave. (iii) *2 : 1, 3 : 1, 4 : 1, Rhythm :* The ventricles respond to every 2nd, 3rd and 4th contraction of auricle. In 2 : 1 rhythm, venous puse wave has twice the number of 'a' wave as compared to the 'c' and 'a' waves. (2) **Complete Heart Block :** When no impulse from auricle reaches the ventricle it is called dissociated rhythm or idioventricular rhythm which is unffected by muscular exercise.

(c) **Bundle Branch Block :** Either right or left bundle branch block is produced when one branch of the bundle of His may be defective. The QRS duration is prolonged.

(d) **Arborisation Block :** This type of block occurs when Purkinje fibres become defective. This is found in chronic myocardial damage and can be detected by electro-cardiogram.

Q. 6. Describe the Nervous Control of Heart Rate.

The heart is a central pumping station situated within the thoracic cavity, always go on contracting and relaxing its activity. During its normal action, it produces 72 beats per minute. The nervous control of heart rate concerns about centres, nerves and reflexes.

Centres : There are higher and lower cardiac centres. The higher centres consists of cortical centres which is situated within the cerebral cortex and the hypothalamic centre situated in the hypothalamus. The hypothalamic centres consists of sympathetic and parasympathetic centres. The lower medullary centres constitute cardio-acceleratory and cardio-inhibitory centres situated in the medulla oblongata of the brain stem.

Nerves : The nerves are of afferent and efferent types. The afferent nerves are the sino-aortic nerves and the afferent vagus. The sino-aortic nerves arise from the presso-receptors of carotid and aortic body and relay to the sensory vagal centre of the medulla oblongata. The afferent vagus nerve arises from the stretch receptor of the heart and relay to the sensory vagal centre of medulla oblongata along with sino-aortic nerves. The efferent nerves are the cardio-acceleratory fibres arising from cardio-acceleratory centre of medulla oblongata and cardio-inhibitory fibres, arising from cardio-inhibitory centre of medulla oblongata of the brain stem and supply to the ventricular musculature of the heart.

Reflexes : (a) Sino-Aortic Relfex :

(1) **During High blood pressure :** In this condition, the stretch receptor and presso-receptors are stimulated and the impulse is reached to the sensory vagal centre. Form there the impulse will go to the cardio-inhibitory centre and then to the motor vagal centre. From there, cardio-inhibitory fibre has been stimulated which produces fall of heart rate.

(2) **During Low blood pressure :** In this condition, the sensory vagal centre has been stimulated by the afferent vagus and the sino-aortic nerves. From there it will go to the cardio-acceleratory centre that will stimulate cardio-acceleratory fibre resulting increased heart rate.

(b) **Marey's Reflex :** In this type of reflex, the heart rate should be decreased due to the stimulation of cardio-inhibitory fibre during increased condition of heart rate.

(c) **Bain Bridge Reflex :** In this type of reflex, the heart rate should be increased due to the stimulation of cardio-acceleratory fibre during fall of heart rate.

Q. 7. Describe the Chemical Control of Heart Rate.

The cardiac centre is highly sensitive to alterations in chemical composition of blood. The changes of oxygen tension, carbon dioxide tension, lactic acid concentration etc. have some effect upon centres, receptors and on plane musculature of the blood vessels.

I. **Action on Cardiac Centres:** The cardiac centres are the cardio-acceleratory and cardio-inhibitory centres which are situated in the medulla oblongata of the brain-stem.

(a) **Effect of Oxygen:** Less amount of oxygen causes increased heart rate and blood pressure. Excess amount of oxygen cause fall of heart rate.

(b) **Effect of Carbon dioxide:** Very slight amount of carbondioxide causes stimulation of cardiac centres producing increased heart rate. Increased amount of carbondioxide causes depression effect upon cardiac centres causing fall of heart rate.

(c) **Effect of Lactic acid**: Lactic acid as a whole has got indirect action upon it. Lactic acld reacts with sodium carbonate produces sodium lactate and carbonic acid and that carbonic acid is broken down into carbondioxide and water. This formed carbon dioxide from lactic acid has got similar effect like the effect of carbondioxide on cardiac centres alone.

II. **Action of Chemoreceptors**: The aortic body is situated in the arch of aorta. The carotid body is situated in common carotid. Both the aortic and carotid body contain pressoreceptors and chemoreceptors.

(a) **Effect of Acid**: Lactic acid and carbonic acid when act upon chemo-receptors, the blood pressure will rise causing increased heart rate.

(b) **Effect of Alkali**: Sodium bicarbonate when acts upon chemo-receptor, it produces depression effect that will lead to fall of heart rate.

III. **Action on Plane Muscle of the Blood Vessels:** The constriction and dilatation of the blood vessels depend upon the direct action of the stimulation of vasoconstrictor and vasodialator centres on the plane muscles.

(a) **Effect of Barium**: It constricts the plane muscle of the blood vessels resulting increased heart rate.

(b) **Effect of Histamine**: It dialates the blood capillaries causing fall of blood pressure producing decreased heart rate.

(c) **Effect of Lead:** It constricts the plane muscle of the blood vessels producing increased heart rate.

Q. 8. Describe the sequence of events during Cradiac Cycle.

The cyclic repetition of the various changes in the heart from beat to beat is known as cardiac cycle. The changes that occur in the heart during one beat are repeated in a similar order in the corresponding beat.

Time Relationships :

A. Ventricular Phase = 0'8 Sec.
  (a) Ventricular Systole = 0'3 Sec.
    (1) Isometric Contraction Phase = 0'05 Sec.
    (2) Maximum Eejction Phase = 0'11 Sec.
    (3) Reduced Ejection Phase = 0'14 Sec.
  (b) Ventricular Diastole = 0'5 Sec.
    (1) Protodiastolic Phase = 0'04 Sec.
    (2) Isometric Relaxation Phase = 0'08 Sec.
    (3) First Rapid Filling Phase = 0'09 Sec.
    (4) Diastasis = 0'19 Sec.
    (5) Last Rapid Filling Phase = 0'5 to 0'1 Sec.
B. Atrial Phase = 0'8 Sec
  (a) Atrial Systole = 0'1 Sec.
  (b) Atrial Diastole = 0'7 Sec.

Description of the Ventricular Phase : The ventricular phase consists of ventricular systole and ventricuar diastole.

(a) **Isometric Contraction Phase :** In this phase the ventricular muscle contracts, but there is no shortening of muscle fibres. Due to the contraction, the intra-ventricular pressure rises and as a result atrio-ventricular valve are pushed inside the atrium and there is rise of intra-atrial pressure. The semi-lunar valves are closed and ventricle is working as a closed chamber. Duration = 0'05 Sec.

(b) **Maximum Ejection Phase :** In this phase, ventricle contracts and there is maximum rise of intra-ventricular pressure. A-V valves are pushed downward and as a result there is fall of intra-atrial pressure. The maximum amount of blood is ejected into the great vessels due to the opening of semilunar valves. Duration = 0'11 Sec.

(c) **Reduced Ejection Phase :** Ventricle is still in the contracting phase. The intra-ventricular pressure is greater than the pressure in the great vessels. The semilunar valves are still open and small amount of blood is ejected into the great vessels. Duration = 0'14 Sec.

II. **Venticular Diastole :** Duration = 0'5 Sec. It consists of following phases :

(a) **Protodiastolic Phase :** It is the phase which starts just after the venticular systole. Duration = 0'04 Sec.

(b) **Isometric Relaxation Phase :** All the muscle fibres are in relaxed condition and the length of all the fibres are equal. All the valves are closed and ventricle is working as a closed chamber. Duration = 0'08 Sec.

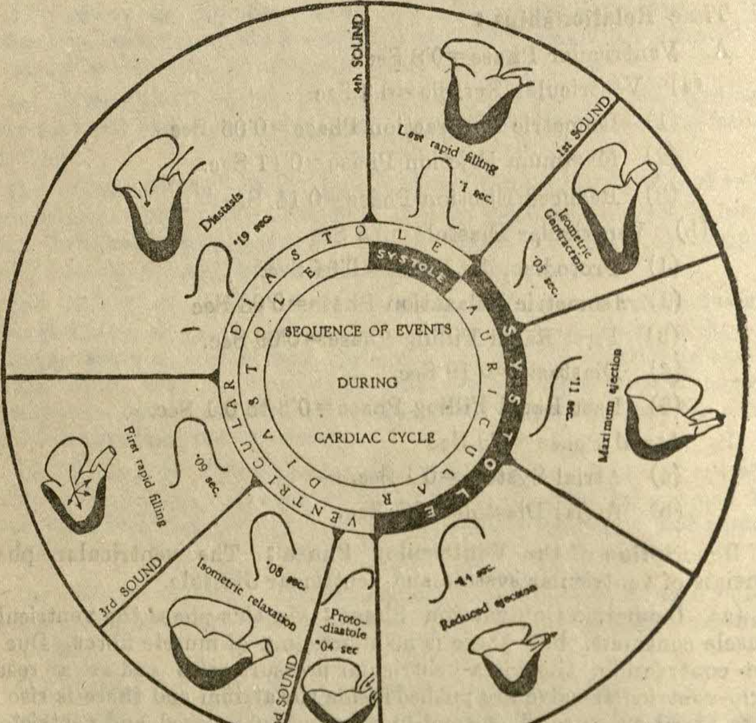


Fig. 12. Diagrammatic representation of the various important events of the cardiac cycle.

(c) **First Rapid Filling Phase :** Blood is accumulated in the atrium and there is the rise of intra-atrial pressure. The intra-ventricular pressure is less than the intra-atrial pressure and so the A-V valves are forced open and blood will enter into the ventricle from the atrium. Duration = 0'09 Sec.

(d) **Diastasis :** Blood will enter slowly from the atrium into the ventricle simply by gravity. Duration = 0'19 Sec.

(e) **Last Rapid Filling Phase :** Due to the contraction of the atrium 40% of the blood enters into ventricle, 60% of the circulating blood enter during first rapid filling phase and diastasis. Duration= 0'05 to 0 1 Sec.

Description of the Atrial Phase :

The atrial phase consists of atrial systole ond atrial diastole.

(a) **Atrial Systole :** Due to the contraction of the atrium, 40% of the blood enters during atrial systole. Duration=0 05 to 0'1 Sec,

(b) **Atrial Diastole :** Duration=0'7 Sec.

(1) Duriug Isometric relaxation phase A-V valves are pushed inside the atrium and there is slight rise of intra-atrial pressure.

(2) In the maximum ejection phase of the ventricular systole A-V ring comes to its normal position, blood is entering into the atrium and so there is gradual rise of intra-atrial pressure.

Changes in the heart during a cardiac cycle :

(1) Spiral arrangement of the muscle fibres makes the contraction of the heart more effective. The blood is wrung out and not pushed. (2) The inter-ventricular septum and apex contract first and so become fixed. The fibrous pericardium cannot move up and so the base of the heart being most mobile part moves down towards the apex. (3) The obliquity of the fibres in the movement of the apex to the right and anteriorly during systole producing the apex beat.

Q. 9. Describe the effect of stimulation of vagus nerve on Toad's heart What is Vagus Escape ? Describe its causes.

Normally the vagus nerve exerts a tonic inhibitory action on the heart. If vagi are cut, the inhibitory influence is lost and the heart rate increased. Stimulation of the right vagus will cause slowing of the atrial beat and as a secondary result of this there is reduction of the ventricular rate and may cause complete stoppage of the heart. Stimulation of the left vagus will cause slowing or complete of the ventricle by depressing the A-V conduction, but there will be no effect on the auricular contraction or auricular rate.

Effect of Vagal Stimulation on Toad's Heart :

Principle : The impulse of heart beat is not only neurogenic in origin but also myogenic and parasympathetic supply control the heart beat. The sympathetic nerve joins the vagus immediately after its exit from the skull of toad and forms vagosympathetic trunk. In this experiment, the vago-sympathetic trunk is stimulated artificially by tetanising shocks to study how it affects the cardiac activity.

Procedure : (1) A toad is pithed and the heart is opened by cutting the abdominal muscle and the pericardium and the nerve is found out. (2) Having exposed the vagus, pass a thread under it but do not tie it. (3) Prepare the coil for giving tetanising shocks. (4) It is best to cut the laryngeal branch of the vagus, because if this be left intact, the muscles contract when the nerve is stimulated and acting upon the pericardium, pull down the base of the heart and so alter the level of the tracing. (5) The whole preparation is now taken on the myograph and the electrode comming from the secondary coil is inserted to the nerve by putting it with the thread. (6) A key is imposed within the drum and the primary circuit. The drum is arranged to move with very slow motion.

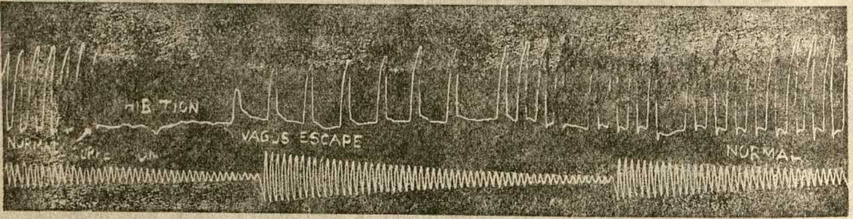


Fig. 13. Graphic Record after effect of Vagus Nerve Stimulation on Toad's heart.

(7) The heart is hang up by the needle of the level and adjusted, some normal contractions are recorded and then the key is opened, the vagus is stimulated and the effect is recorded. (8) After sometime when the key is closed, the heart comes back to normal, the recording is stopped. The record is now traced by a time tracer vibrating per second.

Observations : If the sympathetic fibres are predominating over the parasympathetic ones, the inhibitory effect is more marked with the right vagus than with the left one. (2) Due to the stimulation of vagus, the heart is stopped in a relaxed condition, with continuaton of the stimuli, the heart gradually regains normal condition whichis known as "*Vagus escape*" (3) The heart beats will be arrested due to vagus stimulation after a brief latent period, is known as "*Vagus inhibition*"or heart beats will be decreased in frequency and amplitude. (4) Sometimes the sympathetic effect overpowers the influence of the vagus and produce a short "*After effect*" which is usually increased in frequency and amplitude. (5) The returning beats frequently show the "*Staircase effect*".

Vagus Escape of the Heart : When complete stoppage of the heart is caused by vagal stimulation, the ventricles but not the atrium commence to beat again after a time though the stimulation of this nerve is continued. This is called as the *Vagus escape of the heart*.

Causes of the Vagus Escape : The causes of the vagus escape are the following : (1) The distention of the auricles and the root of the great veins by the accumulation of blood during the period of cardiac stopp age is one of the factor. (2) During complete heart block, the ventricle originates its own rhythm. (3) The blood pressure falls due to either the stoppage of the ventricle or due to the slowing of the heart rate. The sino-aortic nerve will inhibit the cardio-inhibitory centre and will stimulate the cardio-acceleratory centre and the efferent sympathetic nerve will cause contraction of the ventricle. (4) In frogs and toads, the sympathetic fibres pass through vagus and during continued stimulation to vagus becomes fatigued much earlier than the sympathetic.

Q. 10. Describe the different Heart Sounds.

The heart sound are the acoustic phenomena that accompany the cardiac cycle and are intimately connected with the valvular mechanism. There are four types of heart sounds. The first two sounds are very readily heard by applying the ear to the thorax over the heart or by means of stethoscope. The last two sounds (third and fourth sound) are difficult to detect clinically and constantly found in graphic records.

Methods of Study: There are different methods by means of which the different heart sounds can be heard or recorded. The methods of study are: (1) *Clinical Stethoscope*: It is the commonest instrument used for detecting and demonostrating the first and second heart sounds. (2) *Microphone*: By this instrument, the four types of heart sounds can be detected accurately by graphical record. The microphone is applied to the precordium and connected to an Oscillograph. It is also connected with a mirror arrangement that reflects a beam of light on a moving photographic plate.

Description of Different Heart Sounds: There are four sounds of the heart. The first two sounds can be detected by Stethoscope and last two sounds can be graphically recorded by Microphone. The first and the second sounds are closed to each other. There is a longer pause after the second sound. The different types of heart sounds are discussed below:

I. First Heart Sound:

(a) It is dull, prolonged and low pitched. It resembles the word "L—U—B—B".

(b) **Where it is best heard?** It is best heard on the apex beat which is situated in 3½ inch away from the mid-sternal line in the left 5th intercostal space.

(c) **Duration**: 0·1 to 0·17 Sec. time and long and half the ejection period.

(d) **Relation with Cardiac Cycle**: It occurs during the Isometric contraction phase of the ventricular systole and the ejection phase.

(e) **Causes or Factors**: (1) *Muscular Cause*: Due to contraction of muscles of both the ventricles simultaneously, (2) *Valvular Cause*: Sudden closure and tension of the A-V valves. (3) *Mediastinal Cause*: Vibration of the structures in the madiastinum and chest wall produced by the movement of the heart and is impact against the chest. (4) *Vascular Cause*: Vibration set up by the movements of the column of blood.

(f) **Experimental Evidences :** (1) When the ventricular muscle is weak, the first heart sound becomes very feeble. (2) When A-V valves are damaged, the first sound is replaced by murmur.

(g) **Frequency of vibration of sound :** 25 to 45 per second.

(h) **Significance :** (1) It indicates the commencement of ventricular systole. (2) A clear first sound indicates that ventricular contraction and closure of A-V valves are occuring simultaneously. (3) Loud first sound indicates the hypertrophy of the ventricle. (4) The duration and the intensity of the first sound indicate the condition of the myocardium. If the myocardium is weak, the first sound will be short and low pitched.

(i) **Electrical Record :** It coincides with the spike of the R wave of the Electrocardiogram and just preceedes the onset of the C wave of the venous tracing.

(j) **Clinical Identification :** It can be identified by its nature comes just after the pause and just before the radial pulse.

II. **Second Heart Sound :**

(a) **Nature :** It is short, abrupt, clear, sharp and high intensity. It resembles the word "D—U—P". The pitch being higher.

(b) **Where it is best heard ? :** It is best heard over the pulmonary and aortic areas i.e. on the second right costal cartilage or second right intercostal space (at the base of the heart) i.e. where the aorta lies nearest the surface.

(c) **Duration :** 0·1 to 0·14 Sec. time and shorter than the first sound.

(d) **Relation with Cardiac Cycle :** It occurs during ventricular diastole and closure of the semilunar valves in the arota and pulmonary artery.

(e) **Cause :** Due to simultaneous closure of semilunar valves in the arota and pulmonary artery, vibrations will set up in the arterial wall.

(f) **Experimental Evidences :** When the semilunar valves are damaged, the second heart sound is replaced by murmur.

(g) **Frequency of Vibration :** The sound is composed of 3 or 4 principal vibrations with a frequency of 50 per second.

(h) **Significance :** (1) It indicates the commencement of the ventricular diastole after the end of systole. (2) Its pitch is directly proportional to the blood pressure. (3) The interval between first and second sounds is taken as clinical systole and that between the second and first as the diastolic period of heart. (4) The clear second heart sound indicates simultaneous closure of the aortic and pulmonary valves and there is no regurgitation of blood.

(i) **Electrical Record :** It corresponds to the notch which is constantly present on the upstroke of the 'V' in jugular tracing wave in optical records ; it may preceede or follow the end of the T-wave.

(j) **Clinical Identification :** The second heart sound can be clinically identified by its nature, its relation with first sound and the pause and by its coming just after the apex beat and the carotid pulse.

III. **Third Heart Sound :**

(a) **Where it is best heard ? :** It is best heard at the apex beat. It can be detected in 60% of the normal subjects but in actual practice, it is difficult to detect clinically.

(b) **Duration :** It takes 0·4 Sec. time.

(c) **Relation with Cardiac Cycle :** The sounds take place during first rapid filling phase and the ventricular diastole.

(d) **Cause :** Due to the rapid flow of blood from atrium to ventricle and vibration is produced at the A-V valves and in the walls of the ventricles and this vibration is responsible for third heart sound.

(e) **Electrical Record :** It coincides with the last portion of the descending limb of the 'V' wave of the jugular pulse.

(f) **Clinical Identification :** The third heart sound can be identified by its relation with the second sound.

IV. **Fourth Heart Sound** (Auricular Sound) **:** It cannot be heard by clinical stethoscope by auscultation but can be recorded graphically by microphone in cases of complete heart block. It occurs during the last rapid filling phase of ventricular diastole due to the contraction of the atrium, blood rushes into the ventricle producing vibration of the A-V valves and ventricular walls. It is a complex group of vibrations commencing with the rise of the 'a' wave of the venous pulse. In complete heart block cass, the sound then follows regularly on each 'P' wave (which represents auricular fxcitation) and shows up clearly when separated by long interval rom the sounds resulting from ventricular activity. If any disturbance occurs in the pressure and time relations between the different chambers of the heart, instead of one sound, two sounds may be heard at each time and thereby the reduplication of the sounds occur in cardiac diseases.

Q. 11. What is Cardiac Output ? What are the factors essential for cardiac output ? How will you determine cardiac output ?

The cardiac output is the amount of blood which pumped out per ventricle or either of the ventricle during one minute due to the systolic condition of the heart.

$$\therefore \text{ Cardiac output} = \text{Beat output} \times \text{total beat per minute.}$$
$$= 70 \text{ ml.} \times 72$$
$$= 5040 \text{ ml.} = 5 \text{ litres (Approx.)}$$

N.B. *Beat Output* : The amount of blood which passes from either of the ventricle to the aorta or pulmonary artery during each systole of the ventricle is called beat output. The amount of blood in each beat becomes 70 ml.

Factors essential for Cardiac Output :

(a) **Venous Return :** The greater venous inflow will cause increase cardiac output.

(b) **Frequency of heart rate :** The increase rate of the heart will increase the cardiac output provided the venous return is normal or it increases.

(c) **Force of the heart :** The stronger the contraction, greater will be the cardiac output provided the venous return is increased.

(d) **Blood Pressure :** It varies as the product of cardiac output and peripheral resistance.

(e) **Metabolism :** In any condition, if the metabolism in increased, the cardiac output will be increased.

(f) **Posture :** The minute volume is greater in the recumbent posture than in standing.

(g) **Sleep :** The cardiac output may reduce slightly.

Determination of Cardiac Output :

I. **Indirect Methods :** This method is applicable in case ef *animals*. The different indirect methods for the determination of cardiac output in animals, are :

(a) **Cardiometric method of Henderson :** The method is discovered in 1906. For recording the stroke volume in animals with opened thorax, a cardiometer is slipped over the heart. A rubber diaphragm with its hole is tied to the margin of the opening which accurately fits the heart and lies in the atrio-ventricular groove. The tube of the cardiometer is connected with a piston recorder. During diastole the ventricles increase and during systole they diminish in volume. The disadvantages of this method are upon chest and that the inertia and friction of the moving parts deform the curve.

(b) **Knowlton-Starling Heart-Lung Preparation :** This method is done by *Knowlton* and *Starling* in 1913 by experiment for studying cardiac output under different conditions. The procedure is as follows :

The thorax of an animal is opend, heart is exposed and artificial respiration carried out. The vagi served to prevent variation of heart rate. The aorta is beyond the innominate artery in which a cannula is inserted. All blood is diverted through the innominate artery and the cannula into an artificial "resistance" made up of a rubber enclosed in a glass tube. The pressure on the rubber tube can be varied at will. From the "resistance" blood is returned to the right auricle and then to the right ventricle. The latter pumps it into lungs where blood gets oxygenation and is returned to the left atrium and then to the left ventricle. In this way circulation is going on. The pressure, temperature, H-ion, inorganic ions etc. can be varied and their effects on the output noted.

(c) **Steward and Hamilton's Dye dilution method :** (Injection method) : This was first devised by *Stewart* and later perfected by *Hamilton* and his co-workers such as *Kinsman* and *Moore* in 1929. The procedure is as follows :

A known amount of non-diffusible dye, such as T-1824 (Evans blue) is injected into peripheral vein or preferably through a catheter into right atrium. The samples of arterial blood are taken one to two seconds and the concentration of dye in each sample is determined.

II. **Direct Method :** (*In Man*) : This method is only applicable in case of man.

(a) **Fick Principle :** The arterial blood is obtained by arterial puncture in man and the O_2 content is determined. The mixed venous blood is withdrawn by a catheter inserted via the antecubital vein from the right ventricle and its O_2 content is determined. The O_2 usage is determined simultaneously by means of closed circuit by spirometry. *Fick* has shown that cardiac output can be calculated by noting certain data about O_2 or CO_2 exchange.

Applying Carbon dioxide :

Carbondioxide output per minute = 200 ml.

CO_2 content of 100 ml. mixed venous blood = 52 ml.

CO_2 content of 100 ml. arterial blood = 48 ml.

The Veno-Arterial CO_2 difference per 100 ml. = 4 ml.

The general formula used in the calculation is :

$$\therefore \text{ Cardiac Output (ml.)} = \frac{CO_2 \text{ output in ml./min.}}{\text{Veno-Arterial } CO_2 \text{ diff. (ml.\%)}} \times 100$$

$$= \frac{200}{4} \times 100 \text{ ml} = 5 \text{ litres}$$

Applying Oxygen :

Oxygen utilisation per minute = 200 ml.

O_2 content of 100 ml. arterial blood = 19 ml.

O_2 content of 100 ml. mixed venous blood = 15 ml.

The Arterio-Venous O_2 difference per 100 ml. = 4 ml.

The general formula used in this calculation is :

$$\therefore \text{ Cardiac Output (ml.)} = \frac{O_2 \text{ usage in ml./min}}{\text{(A-V) } O_2 \text{ diff. in ml./100 ml.}} \times 100$$

$$= \frac{200}{4} \times 100 \text{ ml.} = 5 \text{ litres.}$$

(b) **Radio-isotopic Method :** Usually I^{131} which is combined with protein to prevent loss from the vascular system is used. A scintillation detector probe is focussed over the aorta. This detector is connected to a count rate meter which activates a recorder.

III. **Physical Methods :**

(a) **Roentgen-Ray Method** (Hirsch and Schwarzschild) **:** It is a method of determining cardiac output by estimation of the difference in the areas of the systolic and diastolic heart shadows by Roentgen rays. This has been done by carefully timing instaneous exposures at systole and diastole or by Roentgen Kymography.

(b) **Ballistocardiogram :** It was discovered by *Henderson* and later on modified by *Starr* in 1939 and *Pordy* in 1951. The procedure is as follows :

The subject lies on a suspended table. The movements of the table are amplified optically and recorded photographically. The picture obtained contains a series of waves bears a relationship to the cardiac output. The normal Ballistocardiogram shows following distinct waves known as HIJKOLMN, of which HIJ are the systolic waves. H-wave is the small positive wave and occurs due to headward movement of the body in response to footward movement of the heart. I-wave is the negative wave and occurs due to footward movement of the body in response to ejection of blood into the aorta during ejection phase. F-wave is a large positive wave due to rapid flow of blood through descending aorta.

Q. 12. What is Blood Pressure ? What are the different types of blood pressure? What are the factors maintaining andinfluencing blood pressure in man ? How will you determine Blood pressure in man ?

The blood pressure is the lateral pressure of the blood exerted on the walls of the blood vessels by the blood due to the systolic condition of the heart. The normal blood pressure of man becomes 130 mm. of mercury (Systolic) and 70 mm. of mercury (Diastolic).

Different Types of Blood Pressure :

(a) **Systolic Pressure :** It is the maximum pressure of blood during systolic condition of the heart. In adult, it becomes 110 to 140 mm. Hg., in chidren, 90 to 110 mm. Hg and in old age it becomes 140 to 150 mm. Hg.

(b) **Diastolic Pressure :** It is the minimum pressure of blood during the diastolic condition of the heart. In children, it becomes 55 to 65 mm. Hg, in infants, 45 to 55 mm. Hg, in adults, 70 to 80 mm. Hg, but in old age it becomes 85 to 95 mm. Hg.

(c) **Pulse Pressure :** It is the difference between systolic and diastolic pressure. It becomes 35 to 40 mm. Hg.

(d)**eanM Aortic Pressure :** It is usually given as half of the sum of the values of systolic and diastolic pressure. It becomes about 100 mm. Hg.

Factors maintaining Blood Pressure :

(1) **Cardiac output :** Blood pressure varies as a product of the cardiac output and peripheral resistance. The cardiac output depends upon venous return, elastic condition of the arterioles, amount of blood ejected out, force of contraction of the heart and frequency of heart beat.

(2) **Peripheral resistance :** The peripheral resistance is found mainly in arterioles and to a minor extent in the capillaries. The peripheral resistance depends upon the velocity and viscoisty of blood and lumen of the arterioles.

(3) **Elasticity of the blood vessels :** The elasticity helps in the regulation of arterial blood pressure. In the old age, elasticity diminishes and blood pressure increases, even when the cardiac output remain constant because blood cannot be properly accumulated by the distention of the arteriolar walls.

(4) **Volume of blood content :** Increased blood volume will raise blood pressure where as diminished blood volume will decrease blood pressure.

(5) **Vaso-motor centre :** The vaso-motor centre maintains the tone of blood vessels by constantly sending tonic impulses to the blood vessels through vaso-contrictor fibre. Destruction of the vaso-motor centre will cause dilatation of the blood vessels and there will be fall of blood pressure.

Factors influencing Arterial Blood Pressure :

(1) **Age :** In young age, the blood pressure is increased but in old age blood pressure falls.

(2) **Sex :** After puberty the systolic pressure in females is lowered by 5 mm. Hg. than males.

(3) **Body build :** In thin subject, the blood pressure is lowered than robust person.

(4) **Digestion :** After digestion of food, blood pressure rises by 5 to 10 mm. Hg.

(5) **Emotional excitement :** During this stage the blood pressure will rise due to the secretion of adrenaline which increases the force of contraction of the heart and causes the constriction of the peripheral blood vessels.

(6) **Muscular exercise :** In severe muscular exercise the systolic pressure may rise up to 200 mm. Hg,

Determination of Blood Pressure in Man : The blood pressure in man can be measured with the help of an apparatus known as Sphygmomanometer.

Principle : The principle employed consisting of a rubber bag which is put around the arm and connected to a manometer ; air is pumped in till the pulse disappears at the wrist owing to the pressure inside the artery producing balancing air pressure against the pressure of the blood in the brachial artery and estimating the former by means of a mercury manometer.

Apparatus Required : The apparatus required for the determination of blood pressure in man are : (1) Sphygmomanometer. (2) Stethoscope.

Description of the Apparatus : The Sphygomomanometer consists of a mercury reservoir, a mercury manometer, a rubber bag along with a cuff, a pressing ball, a loosing screw and the long ruber tubes. This apparatus is described as : (1) A *mercury resrvoir* is made ot wide short glass tube used for the storage of mecury. (2) The *mercury manometer* is made up of graduated glass tube which indicates the different types of blood pressure during measurement. (3) The

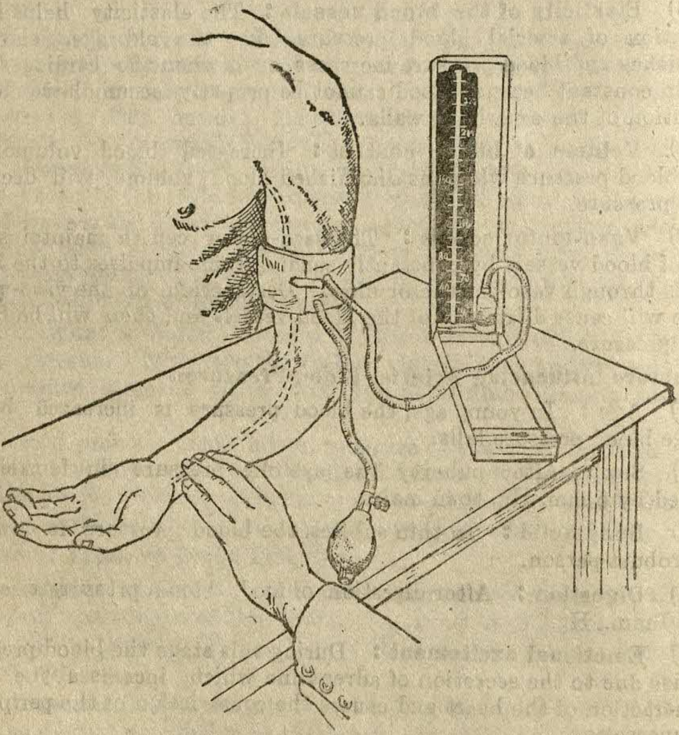


Fig. 14. Sphygmomanometer Instrument showing measurement of Blood Pressure in Man.

rubber bag is made up of rubber externally coered by black silken cloth and an extra piece of silken cloth is attached to it which is known as cuff and it is used for winding the arm above the bend of the elbow. (4) The *pressing ball* is for giving the pressure over the brachial artery and as well as the mercury column will rise into the mercury manometer which will determine the pressure of blood of an individual. (5) The *loosing screw* is attached with the lower end of the pressing ball. It is used for lowering the pressure of mercury from the manometer and adjusts the mercury column in the manometer during recording of blood pressure. (6) The *long rubber* tubes are connected with the mercury reservoir, pressing ball and the cuff. These tubes are used for the conduction of pressure.

Procedure : Wind the arm with the rubber bag with connecting tubes directed downwards over the upper arm, keeping well above the bend of the elbow. Wind the cloth shield around sungly and entirely flat and tuck the end under the last turn.

(a) Palpation Method : Close the screw needle valve on the inflation bulb. Hold the inflating bulb in one hand and palpate the radial pulse with the other, using the fingers and not the thumb for palpation. Inflate the cuff until the mercury has risen abeve the level at which the pulse disappeared. Lossen the screw valve slight so as to allow the pressure to fall at a rate of about 1 m.m. Hg. per second. Record the level of the mercury at the first return beat of the radial pulse which is *Systolic Pressure*. Note level of pressure at the point where the oscillations of the mercury column become the greatest, as the pressure is allowed to fall very gradually to zero and it is the *Diastolic Pressure*.

(b) Auscultation Method : Place of stethoscope in the ears, inflate the cuff as before and place the chest piece of the stethoscope over the brachial artery just below the edge of the cuff at the bend of the elbow. Now arise the pressure in the cuff above the level at which the pulse disappear, then gradually release the pressure and listen carefully and not the height of the mescury column when you hear the first thumb synchronous with the pulse. This reading is the auscultatory *systolic pressure*. The *diastolic pressure* is noted at the point of maximum oscillation on slowly releasing air out of the bag.

Q. 13. What is Pulse ? What are the features of radial pulse ? What are the factors concerned in pulse rate ? How will you determine the radial pulse in man ? What are the variation in pulse tracing ? What do you mean by Atrial Fibrillation and Atrial Flutter ?

The pulse is a combination of the waves of the pressure and alteration in the shape of an artery which gives direct information regarding the condition of the elongation and expansion of the vessel walls and the amount and variation of the pressure of the contained blood. The rate of the pulse indicates the condition of the blood flow, formation of large and small primary waves, condition of blood pressure and amount of blood volume and on the other hand the different clinical disorders. Pulse recording is necessary for the determination and geting information of those affairs.

Clinical Features of Radial Pulse :

(a) **Frequency :** This gives usually the rate of the heart but strictly only the number of beats of the left ventricle which produce pulse-waves strong enough to reach the wrist. The rate of the normal pulse bocomes 72 beat per minute which corroespond to the heart rate.

(b) **Force :** Whether it is a strong, bounding pulse or a feeble beat ; this indicates the force with which the heart is beating.

(c) **Rhythm :** It indicates the regularity and irregularity of heart. The irregularity may occur due to irregular cardiac action either in force or in rhythm. The regular rhythm is occassionally interrupted by some irregularity.

(d) **Volume :** It is the amplitude of movement of the vessel wall during the passage of the pulse wave. It indicates the cardiac output. A pulse of large volume is found after exertion and in acute fevers and a pulse of small volume after hæmorrhage,

(e) **Tension :** It is the force necessary to obliterate the pulse and indicate the systolic pressure. It is examined with three fingers side by side on the radial artery. The proximal finger adjusted the pressure, the middle finger remains stationary and only feels the appearance and disappearance of the pulse wave, while the distal finger applies a constant maximum pressure to stop retrograde pulsation.

(f) **Condition of the arterial wall :** For this purpose sufficient pressure should be exerted to empty the vessel of blood and it should then be rolled beneath the fingers against the underlying bone. In young person, the arteries cannot be felt for softness, in older person they are more easily palpable but in disease, it may become thickened.

Factors Concerning Pulse Rate :

(a) **Intermittent systole of the ventricle :** A little amount of blood after thrown into aorta causes increased heart rate due to the intermittent systolic condition of the ventricle.

(b) **Quantity of the output :** If large quantity of blood output occurs, it will cause increased pulse rate, if small quantity, the decrease pulse rate happens.

(c) **Manner of the output :** The output of the blood due to systolic condition of the heart maintains the different conditions of pulse.

(d) **Elasticity of the blood vessels :** Less elasticity of blood vessels causes increased pulse rate but the rate beocmes decreased due to increased elastic condition of the blood vessels.

(e) **Peripheral resistance :** If it is increased, the pulse rate will increase otherwise the rate becomes slow.

Determination of Radial Pulse : The radial pulse is determined with the help of an instrument known as Dudgeon's Sphygmograph. The physician usually feels the pulse in the radial artery since this is near the surface and supported by bone. It is a most valuatble of the condition of the patient's heart and vessels,

Principle : The apparatus is attached by a leather band round the wrist in such a way that the small rubber button rests on the skin over the radial artery. The movements of the arterial wall, magnified by the series of levers, recorded by the free end of the lever which writes on a moving strip of blackened smoke paper. The paper is moved by small clock work arrangement over two revolving rollers and the pressure of the button on the artery can be adjusted so as to obtain the best record of writing of the pulse curve, by means of the dial.

Procedure : (1) Feel the pulse in radial artery. The position of the artery should first be marked with ink and then the instrument placed on the wrist so that the button lies directly over this mark. (2) During the use of sphygmograph, the pressure upon the spring is exerted that will allow the variations in pressure within the artery to be most manifest. (3) The tracings are taken on slips of glazed paper smoke over a lamp, Jacquet's sphygmo-chronograph is used for time marking. (4) Make an enlarged drawing of the rocord, marking the different parts of the waves and explaining notes regarding their significance.

Findings of the Graphic Record : (1) The up-stroke is abrupt and without any secondary wave on it. (2) Near the middle of the down stroke there is a sharp depression called the "*Dicrotic notch*" which is immediately followed by a small wave the "*Dicrotic wave*". (3) The wave from the beginning of the tracing upto the dicrotic notch is called the "*Primary wave*" or "*Percussion wave*" and the whole wave corresponds to verticular systole. The percussion wave is due to the sudden forcing of a fresh quantity of blood by the heart into the elastic aorta. (4) The dictoric notch is due to the sharp fall of pressure caused by the rolling back of aortic blood towards ventricle at the beginning of diastole. It is immediately preceeded

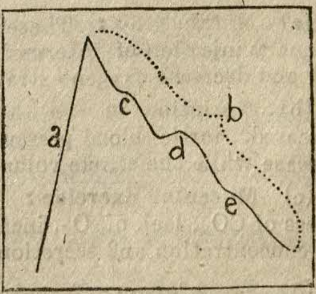


Fig. 15. Graphic Record of Radial Pulse. a—Primary upstroke wave. b—Down stroke. c—Pre-Dicrotic wave. d—Dicrotic wave. e—Post-dicrotic wave.

by the closure of the semilunar valves. (5) The dicrotic wave is caused by the return of the same blood column being reflected back by the closed semilunar valve. (6) Sometimes secondary oscillations are found on the down stroke both above and below the dicrotic wave being known as "Pre-dicrotic" or "Post-dicrotic" waves respectively. These are caused due to elastic oscillations of the aorta.

Atrial Fibrillation : It is a clinical condition in which normal co-ordinate contraction of the atrium is replaced by inco-ordinate contraction of the individual atrial fibers characterised by irregularly irregular pulse. It is frequently observed in mitral stenosis, thyrotoxicosis, myocardial diseases etc.

Atrial Flutter : It is a clinical condition in which there is marked acceleration of the co-ordinate contraction of the atria. The atrial flutter is frequently seen in mitral stenosis, myocardial diseases etc.

Q. 14. What is Coronary Circulation ? What are the factors concerning coronary circulation ? How will you measure the coronary blood flow ?

Heart is the pumping centre of circulation. It circulates blood throughout the body whereby the body gets its nutrition and becomes functional. Being an organ of the body the heart slso have some supply of blood for its nutrition. This supply of blood to the heart is known as coronary circulation. The heart muscles are supplied by two coronary arteries orginating from the aorta close to its orgin. The coronary circulation is one of the shortest circulation of the body. Blood passes through arterioles into a capillary bed and is collected by veins which empty through the coronary sinus into the right auricle.

Factors Concerning Coronury Circulation :

I. General Factors ;

(a) **Metabolities :** These will increase coronary blood flow. The coronary injection of intermediate metabolites will increase coronary flow and decrease oxygen extration.

(b) **Variation in the heart rate :** When the heart rate is increased, aortic blood pressure, minute cardiac output and work increase while the stroke volume and stroke work decrease.

(c) **Muscular Exercise :** The coronary flow is increased due to excess of CO_2, lack of O_2, increased body temperature, increased H-ion concentration and secretion of adrenaline.

(d) **Transfusion :** Transfusion of fluid will increase coronary flow. The coronary flow and oxygen are used for the ratio of cardiac work to oxygen consumption increases.

(e) **Valvular Lesions :** Acute elevation of right ventricular pre-pressure by pulmonary artery constriction initially decreases right coronary flow.

(f) **Heart Failure :** In actue heart failure there will be less coronary flow and less oxygen usuage per minute,

(g) **Shock :** It decreases coronary flow and coronary resistance.

(h) **Aortic Blood Pressure :** The height of the mean aortic pressure and the resistance in the peripheral coronary vessels are the most important factors for determining the coronary inflow.

(i) **Cardiac Qutput :** The coronary flow is directly proportional to the cardiac output. An increase in the cardiac output, increases the coronary flow either by raising the aortic pressure or by reflex inhibition of the vagal vaso-oonstrictor tone.

(j) **O_2 lack and CO_2-excess :** Anoxia or any short of O_2 lack increases the coronary flow to a greater extent. CO_2 excess raises the coronary flow but to a much smaller extent than O_2 lack, because the coronary flow is more sensitive to O_2 lack than CO_2 excess.

(k) **Heart Rate :** The coronary arteries fill during diastole and are compressed during systole. Therefore an increase of heart rate causes shortening of the period of the diastole and thus decreases the coronary flow. The decrease of heart rate has got the reverse action.

II. **Hormonal Factors :**

(a) **Thyroxine :** It increases metabolism which is accompanied by an increase in coronary blood flow or decrease in coronary vascular resistance and an increase in oxygen consumption per minute and per beat.

(b) **Acetyl choline :** This hormone increases coronary blood flow in anaesthetised condition. The increase blood flow response is completely abolished after atropine.

(c) **Pitressin (Vasopressin) :** It alone increaaes coronary resistance to flow. It acts by direct effects on the coronary arterioles and considerably reduces coronary flow.

(d) **Adrenaline :** It causes great dilatation of the coronary vessels and so coronary circulation is increased.

Coronary Circulation : This circulation includes arterial supply and venus drainage.

I. **Arterial Supply :** It includes external supply, anastomoses and internal supply.

(a) **External Supply :** The two right and left coronary arteries are the main arterial supply of the heart which arise from the aorta close to its origin. These are the largest vasa-vasorum as heart was a tube. These are not end arteries but their terminal twigs are called the end arteries. The other negligible supply is done by : (i) Vasa-vasorum of aorta and pulmonary trunk. (ii) Pericardial arteries. (iii) Blood within the left ventricle.

(b) **Anstomoses :** The coronary arteries form three types of anastomoses which are as follows : (i) Anastomoses between the branches of one artery with that of the other. (ii) Communication with the cavities of the heart by some smaller vessels known as Thebesian vessels which open directly into the auricular and ventricular cavity. (iii) Extra-cardiac anastomoses between auricular twigs of the coronary arteries on the one hand and branches of the internal mammary, pericardial, bronchial, phrenic and oesophageal arteries of the other.

(c) **Internal Supply :** Branches of coronary arteries run subpericardial bent at right angle, pierce the myocardium and end on endocardium in a capillary bed which end in a capillary plexus of vein.

II. Venous Drainage : The venous blood from the myocardium is chiefly returned through superficial and deep venous system. The superficial venous system constitutes the coronary sinus, great cardiac veins and anterior cardiac veins. The deep venous system consists of the Thebesian, luminal and sinusoidial vessels.

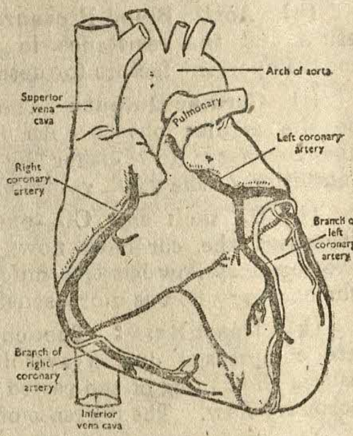


Fig. 16. Anytomy of the heart showing Coronary Circulation.

Measurement of Coronary Blood Flow :

(a) **Experimental Method :** (1) By feeding an excised heart, through the coronary arteries with blood from a pump or heart-lung preparation and collecting the total outflow from the cut pulmonary artery. (2) A cannula is inserted through the wall of the right auricle into the coronary sinus and collecting the blood that pass through the latter. By a comparison of these two methods, it is found in dogs that the flow through the coronary sinus usually forms $\frac{3}{5}$th of the total blood passing through tbe coronary arteries.

(b) **Nitrous Oxide Method :** In intact animals and man, the coronary blood flow to the left ventricle may be measured by the nitrous oxide method. Samples of blood for analysis are taken from the artery, usually the brachial artery and from the coronary sinus via a cardiac catheter, the tip of which is passed into the orifice of the sinus.

(c) **Recent Method :** (1) Some of the problems of external blood counting of radio activity as a measure of myocardial flow have been overcome by the use of Rb^{84} and coincident counting of the gamma rays that are emitted in exactly opposite directions during the decay of the positions formed by Rb^{34} disintegration. (2) Substituting I^{131} labelled antipyrine for nitrous oxide in the Kety method for measuement of coronary blood flow offers certain advantages : (i) The determination is reduced to $2\frac{1}{4}$th. minutes (ii) Simple well-counting replaces manometric analysis for nitrous oxide. (iii) The volume of blood sample is less. (iv) The subject receives an intravenous infusion instead of inhaling a foreign gas via a mouth piece.

Q. 15. Describe the origin of various features of an Electrocardiogram.

The electrical variation produced in the heart during cardiac cycle distributed throughout the body and can be recorded with the help of a sensitive cathode-ray oscillograph or string galvanometer. The graphic tracing is known as *Electrocardiograph*. It is nothing but the action potential changes during contraction and relaxation of the heart. The tracings obtained are electrocardiograms and furnish an important guide in diagnosis and management of patient with heart disease.

Electrocardiographic Leads :

I. **Unipolar leads** (Nahum and Hoff, 1948) : The following unipolar leads are used. They are labelled V, followed by a letter or by a number describing the position of the exploring electrode.

(1) Lead VR—in the right arm.
(2) Lead VL—in the left arm.
(3) Lead VF—left leg (F = foot)
(4) Lead VC—chest.
  (i) V_1 = 4th. intercostal space to right of sternum.
  (ii) V_2 = 4th. intercostal space to left of sternum.
  (iii) V_3 = Midway between left sternal broder and mid-clavicular line on a line joining position 2 and 4.
  (iv) V_4 = 5th. intercostal space in mid-clavicular line.
  (v) V_5 = 4th. intercostal space in left anterior-axillary line.
  (vi) V_6 = 5th, intercostal spaces in left mid-axillary line.
  (vii) V_7 = 5th. intercostal space in left post-axillary line.

II. **Bipolar leads** : These are the leads which have been most extensively used in man, a vast amount of information has consiquently accumulated correlating the electrical with the clinical and post mortem findings. The classical limb leads are :

Lead I : From right arm and left arm.
Lead II : From right arm and left leg.
Lead III : From left arm and left leg.

The deflection recorded in a bipolar limb lead represents the algebraic sum at any moment, of the potentials of the two constituent leads, as follows :

Lead I = Lead VL—VR
Lead II = Lead VF—VR
Lead III = Lead VF—VL

Study of Electrocardiogram : The study of the electrocardiogram show the following five consecutive notches or waves namely P Q R S T from the left hand side. Of these waves there are two iso-electric periods—the shorter one between P and Q while that between S and T is bigger. The P R T waves are upward deflection where as Q and S are downward deflection. In between these five waves the P wave is known as Auricular Complex and the remaining QRST are collectively called as the Ventricular Complex.

P-wave (Activity of the auricle) · This is the first upward deflection having a rounded or pointed top and its duration is 0·1 Sec. It represents the passage of the excitation process from the sinu-auricular node over the auricles. The summit of P indicates that the impulse has reached the A-V node. A normal P wave indicates that : (i) The impulse is originating at the S-A node. (ii) It spreads over the auricles in the usual way. (iii) There is no defect of conduction. (iv) The strength of the contraction of the musculature of the auricles as well as the nutrition is normal.

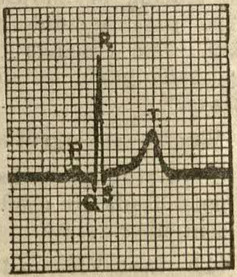


Fig. 17. Human Electrocardigram.

Q-wave (Activity of the septum of the ventricle) : It is a small, often in conspicious, downward deflection. This is caused by the activity of the septum when the impulse reaches it. It is found to be absent in the reptiles and amphibia which does not contains any interventricular septum.

R-wave (Ventricular activity) : It is the most prominent upward deflection. The mechanical contraction of the ventricles and the first heart sound commences at about the down stroke of R.

P-R Interval : This is the interval which measures the conduction time of impulse from S-A node to the A-V node. In health it is 0·13 to 0·16 seconds, the extreme limit of normal being 0·2 second. This interval is found to be shorter than normal which signifies that the impulse probably has arisen in A-V node and has therefore excited the ventricles sooner.

S-wave (Ventricular activity) : It is a prominent downward deflection. In lead I it is caused mainly by the left ventricular activity but in the Lead III this is just the reverse.

QRS Complex : The complex usually lasts less than 0·08 second and should not exceed 0·1 second.

T-wave (Functional state of the base of the heart) : R-wave is followed by a long iso-electric period, after which comes the last upward deflection T. T-wave is related to the functional state at the base of the heart. In young healthy adults the T-wave is very conspicious and has the duration of 0·27 second but in old age it becomes gradually flattened up. T-wave is influenced by the following factors : (i) It is altered by stimulation of vagus or sympathetic nerve. (ii) Exercise in healthy heart increases amptitude. (iii) Anoxia and other some poisons affect it. (iv) In Lead III, T is sometime found to be inverted.

QRST-wave : The average duration of this wave becomes 0·43 second.

Interpretations of Electrocardiogram :

(a) **Atrial Complex** (P-wave) **:** It represents the passage of the impulse from the S-A node over the atria, the A-V node is reached at about the summit of P. This wave is some guide to the functional activity of some atrial muscle. In mitral stenosis the left atrium is hypertrophied and correspondingly the P-wave is prominent or bifurcate. In atrial fibrillation the P-wave disappears and is replaced by a series of fine irregular oscillations, corresponding to the rapid irregular excitation of the atria.

(b) **Conduction time of Bundle of His** (P-R Interval) **:** The time interval from the beginning of P to the commencement of R is a guide to the conduction time of the Bundle of His. The P-R interval in health varies between 0·13 and 0·16 second, the extreme limit as a normal being 0·2 second. When it exceeds 0·2 second, there is delayed conductivity in the bundle of His.

(c) **Ventricular Complex** (QRST-waves) **:** QRS presents the stage of ventricular depolarization. It is affected by structural changes in the ventricular muscle and by delay in conduction in the bundle and its branches. The damage to one or both bundle branches leads to prolongation of ventricular depolarization and thus to a QRS complex which exceeds 0·12 seconds in duration. The S-T segment and the T-wave represent the stage of repolarization.

Q. 16. Write short Notes on :

(1) **Cardiac muscle :** It is present in whole of the heart tissue and composed of a number of muscle fibres. Each muscle fibre consists of quadtriangular forked cells with central nuclei and the branches of branch to branch forming a contracting network known as syncytium. It possesses an outercovering ill-defined sarcolemma and jelly like granular sarcoplasma. Each of the muscle fibre is transversely marked by darkly staining bands. **Properties :** The properties of cardiac muscle are the rhythmicity, conductivity, excitibility, contractility, all or none law, staircase phenomenon, tonicity, etc.

(2) **Junctional tissues :** These form a special connecting link between-atrium and the ventricle that conduct the cardiac impulse from one to the other. The juuctional tissues of the heart are of various types which are : (i) - Sino-auricular node, or S-A node, (ii) Auriculo-Ventricular node or A-V node. (iii) Bundle of His or Auriculo-ventricular bundle. (iv) Right bundle of His. (v) Left bundle of His. (vi) Purkinje fibres.

(3) **Apex beat :** It is the outward thrust, felt at the left fifth intercostal space about half an inch inside the midclavicular line. It takes place at the beginning of ventricular systole which is synchronous with the first sound of the heart.

(4) **Heart Block :** It is a condition in which there is defective production of the sino-auricular impulse or its conduction in the heart. There are four main types of heart block which are Sino-atrial block, Auriculo-ventricular block, Bundle branch block and Arborisation block.

(5) **Heart sounds :** These are the acoustic phenomenon that accompany the cardiac cycle and are intemately connected with the valvular mechanism. There are four types of heart sounds. The first two sounds are very readily heard by applying the ear to the thorax over the heart or by means of stethoscope. The last two sounds i.e., third and fourth sounds are difficult to detect clinically and are constantly found in graphic records.

(6) **Pulse :** It is a combination of the waves of pressure and alteration in the shape of an artery which gives direct information regarding the condition of the elongation and expansion of the vessel walls and the amount and variation of the pressure of the contained blood. The rate of the pulse indicates the condition of the blood flow, formation of large and small primary waves, condition of blood pressure and amount of blood volume and on the other hand the different clinical disorders. Pulse recording is necessary for the determination and getting information of those affairs. The radial pulse is determined with the help of an instrument known as *Dudgeon's Sphygmograph.*

(7) **Blood Pressure :** It is the lateral pressure of the blood exerted on the walls of the blood vessels by the blood due to the systolic condition of the heart. There are four types of blood pressure such as systolic pressure, diastolic pressure, pulse pressure and mean pressure. In man, the normal systolic pressure becomes 130 m.m. of Hg., normal diastolic pressure becomes 70 m.m. Hg, pulse pressure pressure becomes 60 m.m. Hg. and mean aortic pressure becomes 100 m.m. Hg.

(8) **Angina pectoris :** It is a condition of the pain with the pectoralis muscle due to the accumulation of metabolites produced during coronary ischaemia. It is a symptom but not a disease and occurs during severe exercise and disappears during rest.

(9) **Coronary Thrombosis :** It is a condition of severe precordial pain due to the occulusion of one or both big branches of the left coronary artery due to intravenous thrombous formation resulting from atherosclerosis.

(10) **Electrocardiogram :** The electrical variation produced in the heart during cardiac cycle distributed throughout the body and can be recorded with the help of a sensitive cathode-ray oscillograph or

string galvanometer. The graphic tracing is kown as *Electrocardiograph.* It is nothing but the action potential changes during contraction and relaxation of heart. The tracings obtained are *Electrocardiograms* and furnish an important guide in diagnosis and management of patient with heart disease. The electrocardiographic leads are the unipolar and bipolar leads. The study of electrocardiogram shows PQRST waves and P-R interval, QRS complex, etc.

(11) **Dextrocardiogram :** If the left branch of bundle of His is damaged or blocked, impulse will travel through the right branch to right ventricle and activity of the right ventricle will be predominate. *Barker* in 1930 shows that the curve has the following characters : (i) Lead I—Initial deflection (R) upwards. (ii) Lead III—Initial deflection (S) downwards.

(12) **Laevocardiogram :** If the right branch of bundle of His is blocked, the activity of the left ventricle will predominate and it is called Laevocardiogram. *Barker* in 1930 shows that the curve has the following characters ; (i) Lead I—Initial deflection (S) downwards. (ii) Lead II—Initial deflection (R) upwards.

CHAPTER EIGHT

RESPIRATORY SYSTEM

Introduction : The respiratory system comprises of a pair of lungs and a series of respiratory passages leading to nasal cavities, nasopharynx, larynx, trachea and bronchi. Respiration is a physico-chemical process by means of which a gaseous exchange takes place in between the organic tissue and the surrounding medium in presence of moisture. The organs concerned are known as respiratory organs and the system concerned is known as respiratory system. The respiratory apparatus contains the vital organs like lungs with accessory respiratory structures, diaphragm, intercostal muscles, two types of movements known as inspiration and expiration. Inspiration helps for intake of oxygen into the lungs from enviornmental air and expiration helps for exit of carbon dioxide from the lung alveolus to the exterior. Inspiration is the active movement while expiration is the passive movement. The

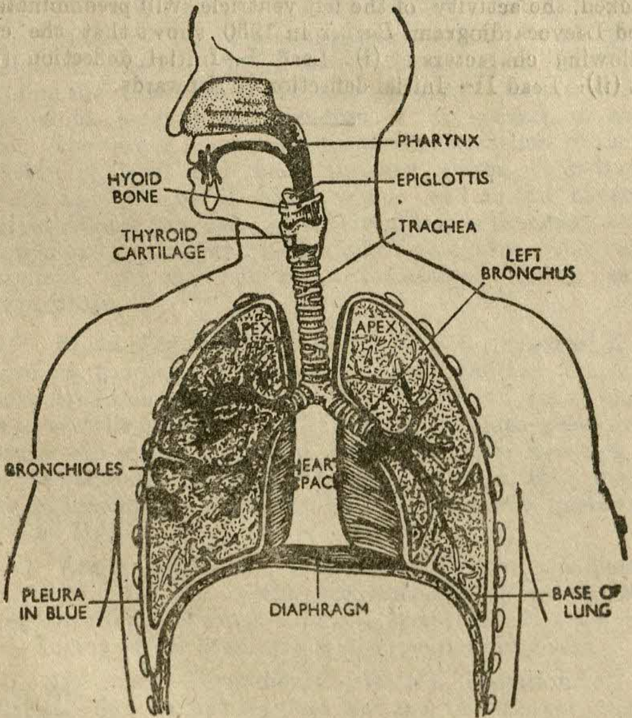


Fig. 18. Diagrammatic Representation of Respiratory Organs.

main respiratory pathway may be summarised as ; Nasal cavity→ Nasopharynx→Larynx→Trachea→Principal bronchus→Primary(lobar) bronchi→Secondary bronchi→Tertiary bronchi→Segmental bronchi →Bronchioles→Terminal bronchioles→Respiratory bronchioles→ Terminal respiratory bronchioles→Alveolar ducts→Atria→Alveolar air sacs→Pulmonary alveoli.

Q. 1. Descrtbe the different structures of the Respiratory Apparatus and discuss the functions of respiration.

The human body constitutes a number of boxes that contain different vital organs and structures which perform different vital functions. The brain is lodged within the cranium or brain-box, heart and lungs are lodged within the chest-box, digestive tubes, liver, spleen, pancreas etc. are lodged within the abdominal-box, urinogenital organ like kidney, ovary etc, are lodged within the pelvic box.

The respiratory apparatus contains the vital organs like lungs with accessory respiratory structures, diaphragm, intercostal muscle, ribs and nerves etc. The description of those structures are discussed as follows :

I. **Lungs :** The lungs are the paired spongy masses situated within the thoracic cavity. The right lung is divided into upper, middle and lower lobes by two deep clefts. The left lung is divided into upper and lower lobes by single deep cleft. Each lung is covered by a visceral membrane known as visceral pleura and another membrane that lines in the inner wall of the thorax and it is known as parietal pleura. In between the two pleura, there is a potential space which is known as Intrapleural space that contains serous fluid. The trachea divides into two principal bronchi—one for the right lung and the other for the left lung. The principal bronchi repeatedly divide into primary or lobar, secondary and tertiary bronchi. These again subdivide into smaller segmental bronchi which further subdivide into primary, secondary and tertiary bronchioles, terminal bronchioles and then into the respiratory bronchioles. Each respiratory bronchiole opens ultimately into the terminal respiratory bronchiole that leads to multiple alveolar ducts Each alveolar duct after a number of branchings leads to alveolar air sacs and pulmonary alveoli.

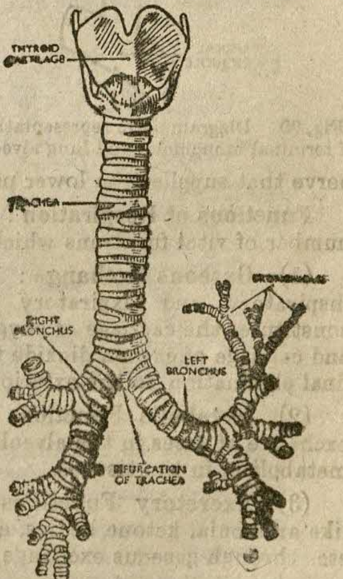


Fig. 19. Anatomical organisation of the respiratory system showing thachea, bronchi and bronchioles.

II. **Musculatures** : The musculatures of the respiratory apparatus constitute the diaphragm and the intercostal muscle.

(a) *Diaphragm* : It is a musculo-tendinous partition that separates the thoracic cavity from the abdominal cavity. By the active movements of diaphragm, expiration and inspiration occur during respiration.

(b) *Intercostal muscle* : This muscle is present in between the two ribs. It helps in the process of inspiration.

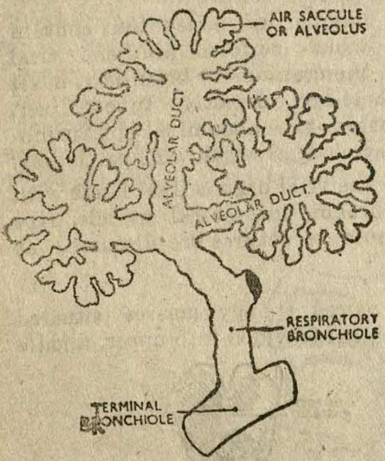


Fig. 20. Diagrammatic representation of terminal bronchioles and lung alveoli.

III. **Skeletal Structures** : There are a number of skeletal structures required to prepare a respiratory apparatus. The thoracic cage is made up of single sternum in front, twelve number of thoracic vertebrae behind and twelve pairs of ribs laterally.

IV. **Nerves** : There are two types of nerves present in the respiratory apparatus that help in the mechanism of the normal respiration. They are afferent and efferent nerves. The afferent nerves are the afferent or sensory vagus and the sino-aortic nerve. The efferent nerves are the intercostal nerves that supply the intercostal muscle and the phrenic nerve that supplies the lower part of the diaphragm.

Functions of Respiration : The process of respiration serves a number of vital functions which are the following :

(1) **Gaseous Exchange** : It takes place in the lung alveoli by the inspiratory and expiratory mechanisms. The gaseous exchange constitutes the carriage of oxygen from the lung alveolus to the tissues and carriage of carbon dioxide from the tissue to the lung alveoli for final elimination to the exterior through different respiratory passages.

(2) **Metabolic Functions** : Oxygen is coming out through exchange of gases in the alveoli which is essential for regulation of metabolism in the tissues.

(3) **Excretory Functions** : Lung excretes volatile substances like ammonia, ketone bodies, essential oils, alcohol and water vapour etc. through gaseous exchange mechanism.

(4) **Acid Base balance Regulation** : The entry of O_2 and exit of CO_2 through gaseous exchange mechanism helps in the maintenance of acid-base balance and thereby blood reaction is regulated.

(5) **Body Temperature Regulation** : During expiration, large

amount of expired air are given out which helps to maintain the normal body tamperature.

(6) **Role of Respiration on Circulation :** (i) The inspiratory process of respiration helps vascular and lymphatic return to thier respective stations. (ii) The process of respiration affects heart rate and cardiac output through nervous mechanism. (iii) The respiratory movements affects the variation of blood pressure. During later part of inspiration and early part of expiration, the blood pressure increases.

Q 2. What is Respiration? Describe the mechanism of respiration.

Respiration is a physico-chemical process by means of which a gaseous exchange takes place in between the organic tissue and the surrounding medium in presence of moisture. It includes two types of movements known as inspiration and expiration. The inspiration is the active movement while expiration is the passive one.

Anatomical Considerations :

(1) **Lungs :** These are the spongy masses of tissue, two in number, situated in the right and left side of the pleural cavities of the thorax. Each lung is made up of a number of alveolus which contain residual air and covered by pleura. The pleura consists of outer parietal layer and inner visceral layer. In between the two layers, there is a potential space known as inter-pleural space that contains seruos fluid.

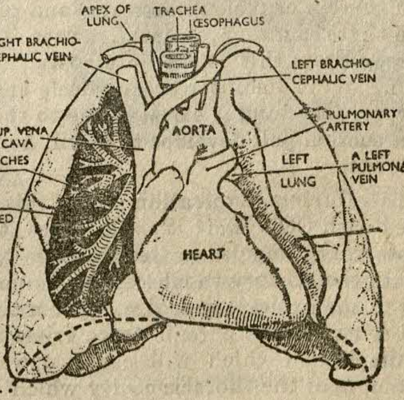

APEX OF LUNG
TRACHEA
ŒSOPHAGUS
RIGHT BRACHIO-CEPHALIC VEIN
LEFT BRACHIO-CEPHALIC VEIN
PULMONARY ARTERY
SUP. VENA CAVA
AORTA
MAIN BRANCHES OF RIGHT BRONCHUS
LEFT LUNG
A LEFT PULMONARY VEIN
RIGHT LUNG PARTLY DISSECTED
HEART

Fig. 21. Anatomical position of the heart and lungs within the thoracic cavity showing lungs, heart, diaphragm and other respiratory structures.

(2) **Diaphragm :** It is a musculo-tendinous partition which separates thoracic cavity from the abdominal cavity. It helps in the process of inspiration and expiration by its upward and downward movements.

(3) **Accessory Structures :** There are a number of accessory respiratory structures which help in the mechanism of respiration. They are trachea, bronchi and its different bronchioles, alveoli, ribs with intercostal muscle and different afferent and efferent nerves.

Physical Mechanism : The inspiration involves the co-ordinated contraction of a large number of muscles and expiration is due to the relaxation of the same group of muscles.

(a) **During Inspiration** : Due to the contraction of intercostal muscle, diaphragm goes downwards and the sternum lifted forwards consequently. During inspiration, the thoracic cavity increases in antero-posterior diameter and the intra-thoracic pressure falls causing elevation of the lungs. With the elevation of lungs, the intra-pulmonary pressure falls and the oxygen sucks in from the atmospheric air.

(b) **During Expiration** : At the end of inspiration, all the intercostal muscles relax, the diaphragm goes upwards, the sternum goes backwards and decreases the antero-posterior diameter of the thoracic cairty. The intra-thoracic pressure rises and the lungs become squeezed and thereby the content of the lungs i.e. CO_2 has been expelled out through the nasal aperture.

Nervous Mechanism : The nervous mechanism of respiration concerns about respiratory centres, afferent and efferent nerves and the respiratory reflexes.

(a) **During Inspiration** : There is little amount of air in the lung which will stimulate the stretch receptor for further entry of air from the exterior. From the stretch receptor, the impulse passes through afferent vagus nerve and relay to the sensory vagal centre. From there a next neurone starts and relay to the inspiratory centre. From there another neurone arises and relay to the motor vagal centre. From this centre, intercostal nerve arises which after stimulation, stretch the intercostal muscle and the thoracic cavity becomes enlarged. The lung is elevated due to the fall of intra-thoracic pressure and a suction pull develops that will help the external air to enter into the lungs.

(b) **During Expiration** : In this condition the lung is fully loaded with CO_2 and it will cause the stretching of the stretch receptors, the impulse passes through the afferent vagus nerve and relay to the sensory vagal centre. From there, a neurone starts and relay to the expiratory centre. From there it will relay to the motor vagal centre. The phrenic nerve arises from there and will stimulate the diaphragm which will cause upward pushing that leads to the shortening of the thoracic cavity which will cause squeezation of the lung and CO_2 is expelled out.

Q. 3. Describe an experiment by which you can record Respiratory Movements.

Respiration includes two types of movements known as inspiration and expiration, Inspiration is the active movement, while expiration is a passive one. Inspiration involves the co-ordinated contraction of a large number of muscles and expiration is due to the relaxation of the same muscles. But both of them follow a normal rhythm. The respiratory movements can be easily recorded by an instrument known as *Pneumograph* which is discussed as follows :

Purpose : Pheumograph is an apparatus to record the rate of respiration i.e. rate of inspiration and expiration of an individual.

Apparatus Required : (1) Pneumograph (2) Marey's tambour and stylus. (3) Jacquet's chronometer. (4) Kymograph, drum and drum-paper. (5) Stands and screen. (6) Rubber tubing.

Description of the Apparatus : (1) Pneumograph is a device for recording respiratory movements by means of a tambour stretched across the individual's chest, with an attached rubber tube for communicating the movement to a recording tambour. (2) Marey's tambour consists of a shallow chamber, one side of which is made of flexible rubber ; this tube connects the chamber with the pulsating part, so that the rubber surface is raised and lowered by the fluctuations of air in the tube. (3) The pointer mounted on the tambour records the rate of respiration on the smoked paper wrapped on the drum. (4) The coiled elastic rubber tube is connected with a chain. With the help of the chain, the elastic tube is tied on the chest or abdomen.

Procedure : (1) After the kymograph was set, the subject was seated beside it comfortably. The pneumograph was first attached to the Marey's tambour by a rubber tube and then it was tied against subject's chest. The pnemograph was tied not too tight. (2) Consequent on the resiratory oscillation, there is an alternate stretching and shortening of the rubber tube which are reflected on the tambour and recorded on the drum paper. (3) The chronometer, marking at on beat per second was taken along with the curve. (4) This method is also repeated after some exercise. The curve obtained this time is bigger in size than the normal one. In this was respiratory rate can be differentiated during the rest and after exercise.

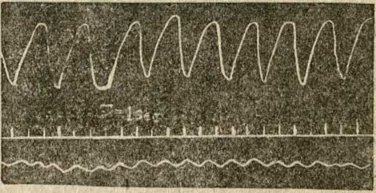


Fig. 20. Graphic Record of Respiratory Movements.

Q. 4. Describe the Respiratory centres in detail.

The respiratory centres are situated in the different portions of the brain stem which concern in the mechanism of respiration. There are a number of theories about the centres of respiration which are as follows :

I. **Lumsden's Theory :** According to this theory, respiratory centres occupy the whole of the fourth ventricle and consist of :

(a) **Pneumotaxic centre :** This centre is situated at the upper part of the pons. It has got inhibitory influence over the apneustic centre. A transverse section below the pneumotaxic centre will produce apneustic type of breathing i.e. prolonged inspiration which may last for 2 to 3 minutes.

(b) **Apneustic centre** : It is discovered by *Wang* in 1964 and situated at the level of the stria-accousticae. This centre has got inhibitory influence over the gasping centre. A transverse section below apneustic centre will produce gasping type of breathing. In the normal act of respiration, apneustic centre due to the property of automaticity will initiate the impulse which will traverse in two directions : (1) The excitatory impulses to the spinal motor neurone controlling the muscles of inspiration and the process of inspiration starts. (2) The excitatory impulses to the pneumotaxic centre which when gets stimulated will inhibit the apneustic centre and as a result, the inspiration stops but expiration starts. According to this theory inspiration is an active process but expiration is purely a passive phenomenon.

II. **Flouren's Theory** : According to this theory, respiratory centre consists of a small area like the head of a pin situated in the floor of the 4th ventricle at the apex of calamus scriptorius. The destruction of this area or section below this area will produce death due to respiratory failure.

III. **Modern Theory** : According to this theory, respiratory centres occupy the whole of the floor of the 4th ventricle and consists of Pneumotaxic centre, Inspiratory centre and Expiratory centre. All the three centres are bilaterally situated.

(a) **Pneumotaxic centre** : It is situated in the pons. It has got inhibitory influence over the inspiratory centre but excitatory influence over the expiratory centre.

(b) **Expiratory centre** : This centre is situated in the medulla oblongata behind the inspiratory centre. The electrical stimulation of the expiratory centre produces expiration and it lasts so long the stimulation is continued.

(c) **Inspiratory centre** : This centre is situated in the medulla oblongata and occupies the cephalic 4/5th of inferior olive The electrical stimulation of this centre produces inspiration and inspiration lasts so long the centre is electrically stimulated. Regarding the inspiratory centre there are different views : (1) **Electron Theory** : The depolarization of the surface membrane of the cells of the inspiratory centre in responsible for the origin of impulse. (2) **Chemical Theory** : The normal CO_2 tension in the blood stimulates the cells of the inspiratory centre to initiate the impulse. When the CO_2 tension of the blood becomes high, there will be more stimulation of the inspiratory centre. Similarly, when CO_2 tension in the blood becomes low, there will be inhibition of the inspiratory centre. (3) **Electron-chemical Theory** : The CO_2 content of the blood is responsible for the depolarization of the surface membrane of the cells of the inspiratory centre to initiate the impulse.

Q. 5. Describe the Nervous Control of Respiration.

Respiration is a physico-chemical process by means of which a gaseous exchange takes place in between the organic tissues and the surrounding medium in presence of moisture. There are several factors, each of which plays an important role in the maintenance and regulation of rhythmic movements of respiration.

Nervous Control : The control of respiration by means of nerves is called nervous control. It is generally grouped into centres, nerves and reflexes.

(a) **Centres** : It is made up of higher centre and lower centre. The higher centre is known as cortical centre which is situated in the cerebral cortex and the hypothalamic centre which is made up of sympathetic and parasympathetic centre that help in the regulation of autonomic functions. The lower centre is known as medullary centre. The vagal centres are of two types known as sensory vagal and motor vagal centres. There are a number of theories regarding respiratory centres.

(1) According to **Lumsden** in 1932, there are three respiratory centres known as *apneustic* or inspiratory centre, *pneumotaxic* or inhibitory centre and *gasping centre*. The apneustic centre is situated at the level of the stria-accoustiae. According to *wang* and his colleagues in 1964 that the apneustic centre is situated in the caudal margin of the trapezoid body. The pneumotaxic centre is situated at the upper part of pons and the gasping centre is situated in the lower part of the medulla.

(2) According to **Pitts, Magoun** and **Ranson** in 1939, there are two respiratory centres known as *inspiratory* and *expiratory centres*. The inspiratory centre occupies the rostral half or 2/3rd of the reticular formation overlying the nuclei on the sides i. e. beneath caudal third of the floor of the fourth ventricle.

(3) According to **Flourens**, the bilateral respiratory centre consists of a small area like the head of a pin is situated in the floor of the fourth ventricle at the level of the apex of the calamus scriptorius and overlaps the sensory centre of the vagus.

(4) According to **Gad**, the respiratory centre occupies the entire formatio reticularis of the medulla oblongata.

(5) According to **Gierke**, the respiratory centre is situated in the tractus solitarius.

(b) **Nerves** : The nerves concerning the mechanism of respiration are of two types known as afferent and efferent nerves. The afferent nerves are the afferent vagus that arises from the stretch receptor of the lungs and the sino-aortic nerve which arises from the pressoreceptors of carotid and aortic body. The efferent nerves are the intercostal nerves that supply the intercostal muscles and phrenic nerve that supplies the lower border of the diaphragm.

(c) **Reflexes :** There are various reflexes that take part in the the nervous regulation of respiration. They are Hering-Breuer reflex, Sino-aortie reflex, visceral reflex and other reflexes.

I. **Hering-Breuer Deflation Reflex :** *Hering* and *Breuer* in 1968 hrve observed that inflation of lungs causing arrest of inspiration but deflation of lungs producing opposite effect.

(a) **During Inspiration :** There is little amount of air in the lung which stimulates the stretch receptor for further entry of air from the exterior. From the stretch receptor the impulse passess through the afferent vagus nerve and relay to the sensory vagal centre. From there a next neurone starts and relay to the inspiratory centre and then to the motor vagal centre. From this centre intercostal nerve after stimulation, stretch the intercostal muscle and the thoracic cavity becomes enlarged. The lung is elevated due to the fall of intrathoracic pressure and a suction pull develops that will help the external air to enter into the lung.

(b) **During Expiration :** In this condition, the lung is fully loaded with CO_2 and it will cause the stretching of the stretch receptor, the impulse passes through afferent vagus nerve and relay to the sensory vagal centre. From there a neurone starts and relay to the expiratory centre and then to the motor vagal centre. From this centre, phrenic nerve stimnlates the diaphragm which will cause upward movement leading to shortening of the thoracic cavity that will cause squeezation of the lung and thereby CO_2 is expelled out.

II. **Sino-Aortic Reflex :** This reflex starts form the pressoreceptor or baroreceptors arising from carotid and aortic body. These are connected with the respirtory centre through sino-aotic nerves.

(a) **During high blood pressure :** In this condition, CO_2 is accumulated in the lungs causing stretching of the lungs that will lead to the stimulation of stretch receptors and pressoreceptors. The sensory impulses pass through the sino-aortic nerve and stimulate the sensory vagal centre. From there, the impulse stimulates the expiratory centre and relay to ths motor vagal centre. From this centre, phrenic nerve stimulates the diaphragm causing upward movement, producing rise of intra-thoracic pressure and thereby CO_2 is expelled out.

(b) **During low blood pressure :** Due to lack of O_2, the stretch receptors and presso-receptors are stimulated and the impulse passes through the afferent vagus and the sino-aortic nerves and relay to the sensory vagal centre. From there, the impulse stimulates the inspiratory centre and then to the motor vagal centre. The impulse passes through the intercostal nerve and stimulate the intercostal muscle causing downward movement of the diaphragm producing fall of intra-thoracic pressure and as a result enviornmental air sucks in.

III. **Reflex from Nose :** The inhalation of irritant gases will inhibit the respiratory centre and there will be slowing in the rate of respiration. Irritant gases will stimulate the receptor present on the nasal mucous membrane and the impulses from the receptors will pass through the 5th cranial nerve which will inhibit the respiratory centre.

IV. **Reflex from Pharynx :** During deglutition, there will be distention of the pharynx. The baro-receptors present on the wall of the pharynx get stimulated, the impulses will pass through the glossopharyngeal nerve which will inhibit the respiratory centre producing temporary stoppage of breathing known as "*Deglutition Apnoea*".

V. **Reflex from Larynx :** When any foreign body is lodged on the mucous membrane of the epiglottis, there will be violent coughing due to the stimulation of the expiratory centre which produces contraction of the expiratory muscles.

VI. **Reflex from Skin ;** The application of hot or cold water on the skin will modify the rate of respiration. The impulses from the skin will stimulate or inhibit the respiratory centre to modify the rate of respiration.

Q. 6. Describe the Chemical Control of Respiration.

The chemical control of respiration has got a valuable role in the process of inspiration and expiration. The important chemicals are oxygen, carbon dioxide, lactic acid, carbonic acid and acid and alkali ions. These chemicals may act upon respiratory centres,chemoreceptors and free nerve endings of muscle.

I **On Respiratory Centres :** The respiratory centres are mainly expiratory and inspiratory centres which are situated in the brain stem.

(a) **Role of Oxygen :** Less amount of O_2 causing depressor effects upon respiratory centre and thereby the rate of respiration becomes slow. Increased amount of O_2 produces stimulation upon respirptory centre and as a result respiratory rate is increased.

(b) **Role of Carbon dioxide :** The respiratory centre is extremely sensitive to slight alteration in CO_2 tension. Slight amount of CO_2 causes stimulation of the respiratory centre that will increase the respiratory rate. Excess amount of CO_2 produces depression of the respiratory centre and as a result respiratory rate falls.

(c) **Role of Hydrogen Ions :** Acid ion causes stimulation of the respiratory centre by which respiratory rate increases. Alkali ion causes depression of the respiratory centre and thereby the rate of respiration decreases.

(d) **Role of Lactic Acid :** It has got indirect effect upon respiratory centres. Lactic acid reacts with sodium bicarbonate and produces sodium lactate and carbonic acid. This carbonic acid breaks down into carbon dioxide and water. This carbon dioxide acts upon respiratory centres as like as it acts alone.

II. **On Chemoreceptors :** The chemoreceptors of respiration are situated in the aortic and carotid sinus.

(a) **Role of Hydrogen Ion :** Acid ion causes stimulation of the chemoreceptor and thereby respiratory rate increases. Alkali ion causes depression effects on chemoreceptor and as a result respiratory rate decreases.

(b) **Role of Lactic Acid :** It acts on chemoreceptor and the rate of respiration increases.

III. **On motor End plate :** The motor endplate is formed either at the junction of phrenic nerve endings and diaphragm or intercostal nerve endings and intercostal muscles.

(a) **Role of Oxygen :** Slight amount of O_2 causes contarction of the nerve endings and thereby respiratory rate increases. Lack of O_2 has got no contraction effects of the nerve endings and thereby respiratory rate increases indirectly.

(b) **Role of Carbon dioxide :** A good amount of CO_2 cause a toxic effect on the nerve endings producing paralysis, but a little amount of CO_2 causes contraction of the nerve endings producing expiration.

Q. 7. Describe the Carriage of Oxygen.

Respiration is a physico-chemical process by means of which a gaseous exchange takes place in between the organic tissue and the surrounding medium in presence of moisture. The oxygen carriage starts from the lung alveolus and reaches to the tissue fluid and blood vessels.

Anatomical Considerations : There are a number of structures concerned during the carriage of oxygen which are lung alveolus, blood vessels, tissue fluid and tissue. (1) **Lung alveolus :** It is formed by the elevation of the tertiary bronchioles. The alveoli are lined by thin, flat pavement epithelium which communicate with each other through perforation. The exchange of gases between the air and the blood takes place in the alveolus. (2) **Blood vessels :** These are elastic tubular channels carrying oxygenated and deoxygenated blood. (3) **Tissue fluid** : It occupies the intercelluar spaces and forms the connecting link in transport of nutrition, gases and metabolic end products between the blood and tissue fluid. (4) **Tissue :** It is a collection of similar types of cells preforming similar type of function having a common origin. It performs the production of carbon dioxide after taking oxygen from the blood.

Factors influencing Oxygen Carriage :

(1) **CO_2 Tension** : More amount of CO_2 tension retards O_2 intake and O_2 dissociation increases. The increased CO_2 tension means that oxyhæmoglobin gives off more O_2 at any given oxygen tension,

(2) **Body Temperature** *:* The rise of body temperature retards O_2 intake and increases the rate of dissociation of oxyhæmoglobin.

(3) **H-ion Concentration :** The increased H-ion concentration prevents the intake of oxygen and thereby O_2 dissociation increases.

(4) **Saline Content of Plasma :** It exerts direct influence upon oxygen carriage.

Oxygen Carriage : This carriage constitutes alveolar carriage and tissue carriage. Near about 19 to 20 ml. of oxygen are carried by 100 ml. of arterial blood and 14 to 15 ml. by 100 ml. of venous blood.

A. **Alveolar Carriage :** This carriage is mainly done in the lung alveolus. The carriage starts from the lung alveolus and ends into the blood vessels via tissue fluid. The oxygen is carried in the blood in the following forms :

(a) **In Physical Solution :** A small amount of oxygen is carried from lung alveolus to tissue fluid and from there it will enter into the blood vessels by tension difference. About 0·30 ml of oxygen is carried in physical solution in 100 ml. of arterial blood under normal conditions of temperature and pressure.

(b) **As Chemical Compound :** The greater part of the oxygen is carried as chemical compound in combination with hæmoglobin present in the R. B. C. and takes place in blood vessels. The oxygen combines with hæmoglobin and forms oxyhæmoglobin compounds. $O_2 + Hb \rightleftarrows O_2\,Hb$. The oxyhæmoglobin compound is loose and reversible. It is quickly formed in the lungs and is quickly dissociated in the tissue capillaries.

B. **Tissue Carriage :** This carriage concerns the carriage of oxygen from the blood vessel to the tissue via tissue fluid.

(a) **As Chemical Compound :** The formed oxyhæmoglobin is dissociated into oxygen and hæmoglobin by the reversible action in the blood vessel. Hæmoglobin is set free and oxygen is carried to the tissue. $O_2Hb \rightleftarrows O_2 + Hb$. As the oxygen combines with hæmoglobin, only the red cells help in the O_2 carriage but not the other elements of blood.

(b) **In Physical Solution :** The released oxygen from oxyhæmoglobin enters into the tissue fluid and reaches into the tissue by tension difference. The arterial blood carries about 19 to 20 ml. of oxygen as oxyhæmoglobin and about 0·30 ml. in physical solution.

Q, 8. Describe the Oxygen Dissociation Curve (Bohr Effect) :

The amount of oxygen which a given amount of hæmoglobin takes up, that is its percentage saturation, is a function of the partial pressure of the oxygen in the atmosphere in contact with it. The graph showing the relation between the two is known as dissociation curve which was first discovered by *Bohr* it 1920 and the shape of the curve becomes 'S' shaped. The position of the dissociation curve depends upon the partial pressure of CO_2, rise of temperature, rise in H-ion concentration or acidity.

Description of Oxygen Dissociation Curve : The partial pressure of oxygen, after equilibrium is reached in the pulmonary capillaries, is about 100 mm. Hg. The partial pressure of CO_2 is about 40 mm. Hg. If there is the normal quantity of hæmoglobin present, the O_2 content of the arterial blood will be 19·7 volumes present. A study of the curves will also reveal that the partial pressure of O_2 may fall considerably before there is a significant decrease in the O_2 content of the blood.

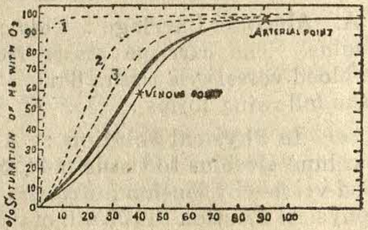
Fig. 21. **Oxygen Dissociation Curves** showing the behaviour of solutions of haemoglobin and of blood under different conditions.

Abscissa—showing O_2 tension in m.m. Hg.

Ordinate—showing % saturation of Hb. with O_2.

Dotted lines—showing Hb. Solution.

1—Room temp. and no CO_2 tension. 2—at body temp. and without CO_2 tension. 3—at body temp. and 20 m.m. CO_2 tension. *Continous line*—blood. *Thick line*—under a tension of 40 m.m. CO_2. *Thin line*—O_2 Dssociation curves.



When the blood reaches the tissue capillaries, the hæmoglobin gives up a part of its O_2 load ; that is, there is a dissociation. This occurs because the partial pressure in the tissues is 40mm. Hg. or less, Reference to the curve discloses that at an O_2 partial pressure of 40mm. Hg. the hæmoglobin is only 75% saturated.

Modification of the Dissociation Curve : The modification of the dissociation curve produced by the CO_2 tension of the blood has biological advantages. In the lungs, where the O_2 tension is high and CO_2 tension is low, the blood takes up more O_2 that it could were the CO_2 content high. When the blood passes to the tissues, where the O_2 tension is low and CO_2 tension high, the hæmoglobin parts more easily with its oxygen. The more active the tissue the more CO_2 does it produce and the increased CO_2 tension, since the dissociation curve is lowered and moved to the right, sets free more oxygen for the respiratory processes of the tissue. Thus the Bohr effect allows the blood to take up more oxygen in the lungs and facilitates the liberation of oxygen from the blood in the tissues.

Effects on Oxygen Dissociation Curve :

(a) **Role of Carbon Monoxide** : The importance of CO-poisoning lies in the fact that coal gas, motor car exhaust, breech gases from guns etc. contain a high proportion of CO. The carbon monoxide forms carboxy hæmoglobin producing hypoxia. The O_2 dissociation curve is moved to the left and it also becomes less 'S' shaped.

(b) **Role of Carbon Dioxide** : The oxygen dissociation curve is influenced by the carbon dioxide pressure. Its partial pressure increases from about 40 m.m. Hg. to 46 m.m. Hg. This increase in the partial pressure of CO_2 shifts the O_2 dissociation curve to the right. In other words, more O_2 is made available to the tissues without lowering of the O_2 partial pressure.

(c) **Role of Acid Metabolites** : It is observed that increased acidity shifts the O_2 dissociation curves to the right. The end products of cellular metabolism are acid metabolites. The increased CO_2 causes greater dissociation of haemoglobin as acid metabolites do.

(d) **Utilization Co-efficient** : The percentage of the total O_2 load given up to the tissues has been termed the utilization co-efficient. The utilization coefficient at rest is about 25% and during extreme excretion, the utilization coefficient may increase to about 75%.

(e) **Role of Myoglobulin** : The moyoglobulin is an oxygen-carrying pigment found in the muscle fibre, may play a very significant role in the transport of O_2 into the cell. It has been suggested that the O_2 molecules are handed down from one myoglobin molecule to another in a chain or "bucket-brigade" fashion.

Q. 9. Describe the Carriage of Carbon dioxide

The carriage of carbon dioxide starts from the tissue and reaches into the lung alveolus via tissue fluid and blood vessels. The carbon dioxide when finally reaches into the lung alveolus, it exits to the exterior through different respiratory passages. The CO_2 carriage concerns about tissue carriage and alveoler carriage.

I. **Tissue Carriage** : This carriage is mainly done by the tissue, tissue fluid and blood vessels.

A. **In Physical solution** : Carbon dioxide is formed in the tissue by the oxidiation of carbon derived from proteins, fats and carbohydrates as a result of tissue metabolism. The carbon dioxide tension in the tissues is increased which is near about 46 m.m. Hg. CO_2 produced is carried by the venous blood into the lungs where the CO_2 escapes partially into the alveolar air. The total amount of CO_2 present in the venous blood becomes 52 ml. per 100 ml. of blood.

CO_2 enters from the tissue side into the blood as a result of pressure gradient factor that the tension of CO_2 in the tissue side is much higher than that in the cappillary blood. So, CO_2 diffuses from the tissue zone into the blood or tissue capillaries.

B. **As Chemical compounds** : The CO_2 after entering into the blood vessel forms a number of chemical compounds either in the red blood cells, plasma or in between R. B. C and plasma.

(1) **In the Red Blood Cells** : (i) As CO_2 bubbles from the tissue fluid into the blood it comes with water of the plasma forming carbonic acid and CO_2 combines with water of the corpuscles forming carbonic acid $CO_2 + H_2O \rightleftarrows H_2CO_3$. The reaction is catalysed by the enzyme carbonic anhydrase which is present inside the R. B C. The carbonic acid thus formed ionises into H^+ and HCO_3^-. (ii) The CO_2 combines with haeglobfn of R. B. C and forms carboxyhaemoglobin $CO_2 + Hb \rightleftarrows CO_2Hb$. (iii) Haemoglobin of R. B. C. combines with K-ion and forms KHb. (iv) K-ions combines with HCO_3-ion forming $KHCO_3$ and H-ion of H_2CO_3 combines with haemoglobin and forms reduced haemoglobin (HHb.)

(2) **In the Plasma** : The carriage of CO_2 is done by means of phosphate buffers in the following ways : (i) The protein portion of the plasma remains combined with sodium and forms sodium proteinate. It will again combine with carbonic acid and forms sodium bicarbonate and reduced protein. $NaPr + H_2CO_3 = HPr + NaHCO_3$.

(ii) The alkaline phosphate combines with carbonic acid and forms sodium bicarbonate. $Na_2HPO_4 + H_2CO_3 = NaH_2PO_4 + NaHCO_3$.

(3) **In between R.B.C. and Plasma :** In between plasma and red blood cells, gaseous exchange takes place by the concentration of their ions and also by the formation of carbamino-compounds. The interchanges can be explained easily on the principle of Donnan equilibrium and chloride shift.

(a) **Donnan's Equilibrium** : Owing to the peculiar properties of the membrane of the red cells, certain important ionic changes takes place between the plasma and the corpuscles whenever CO_2 enters or leave the blood. The membrane lets through the negatively charged acid cations (i.e. $Cl.^-$, HCO_3^-) but is impermeable to the positively charged basic anions (i.e, Na^+, K^+, H^+). The anions and cations conseqently distribute themselves between the plasma and corpuscles according to Donnan's equilibrium. The principal relationship that concern us here are :

$$\frac{HCO_3^-(\text{Plasma})}{HCO_3^-(\text{Cells})} = \frac{Cl^-(\text{Plasma})}{Cl^-(\text{Cells})} = \frac{H^+(\text{Cells})}{H^+(\text{Plasma})}$$

(b) **Chloride Shift or Hamburger Phenomenon or Bicarbonate-Shift :** The potassium bicarbonate within the corpuscles will dissociate into K^+ and HCO_3^-. At the same time, there will be dissociation of NaCl into Na^+ and Cl^-.

The corpuscular membrane is permeable to negatively charged ions and impermeable to positively charged ions. The Cl^- of the plasma derived from NaCl passes into the corpuscles and combines with K^+ forming KCl.

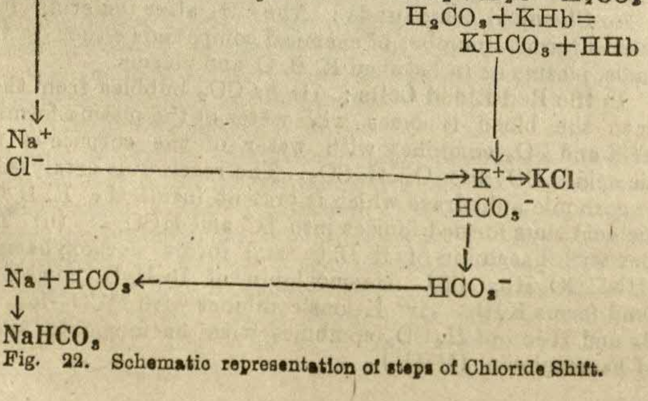


Fig. 22. Schematic representation of steps of Chloride Shift.

So, nature allows the requisite number of HCO_3^- ions to come out of the corpuscles and thereby to maintain equilibrium and the latter combine with the free Na^+ions in the plasma left over to form $NaHCO_3$ in the plasma. Thus as a result of CO_2 migrating from the tissue into the blood we find a coincident rise of corpuscular chloride along with the fall of plasma chloride and a rise of plasma bicarbonate. This is the *Chloride Shift or Bicarbonate Shift* from the tissue side.

(c) **Carbamino-compound formation :** The small amount of carbon dioxide will combine with plasma proteins and forms carbamino-compound. $CO_2 + Pr.NH_2 \rightleftarrows PrNH.COOH$.

II. **Alveolar Carriage :** This carriage concerns about the lung alveolus, tissue fluid and blood vessels.

(a) **As Chemical compound :** The CO_2 is dissociated from carbonic acid, carboxyhaemoglobin, potassium bicarbonate, carbamino-compound etc. and enters into the tissue fluid.

(b) **In Physical solution :** The dissociated CO_2 enters into the plasma of the blood vessels and passes through tissue fluid and lung alveolus by tension difference and ultimately comes to the exterior.

Q. 10. Describe the Carbon dioxide Dissociation Curve.

The carbon dioxide dissociation curve of blood can be determined by equilibrating samples of blood with known tensions of CO_2 and measuring the CO_2 content of the equilibrated samples. The important informations have been gathered regarding the behaviour of CO_2 of blood under different physiological conditions with the help of a comparative study of CO_2 contents of reduced blood, oxygented blood, bicarbonate solution and water and under different pressures of CO_2. The CO_2 dissociation curve forms when the results are plotted in the form of curves. The following facts are seen from this curve, which are : (1) In a vacuum, CO_2 content of blood is nil. (2) At any stage of CO_2 tension, reduced blood taken up CO_2 in larger amount than oxygenated blood. (3) CO_2 is evolved from the lungs during oxygenation of blood. (4) As the CO_2 tension is increased, CO_2 content of blood increases and as CO_2 tension falls, CO_2 content of blood diminishes.

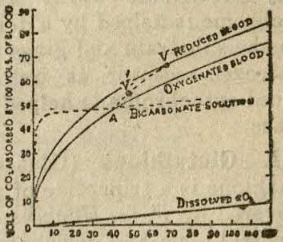


Fig. 23. **CO_2 Dissociation Curves of Blood.** A = Arterial point (40 m.m. Hg. CO_2 pressure). V = Fully reduced point. V′ = Mixed venous point (46 m.m. Hg. CO_2 pressure). *Straight Line* = Dissolved CO_2 in physiological solution. *Interrupted Line* = Dissociation curve of bicarbonate soluion.

Q. 11. Describe the process of Tissue Respiration.

Tissue respiration is an exchange of hydrogen and oxygen sometimes carbon dioxide from one substance to different substances, finally combind with the O_2 to form water with the help of so many intermediate compounds, they are called carriers. This carrying may take place by some enzyme. The main scheme of the transference, original substrate is oxidised, though this substrate cannot combine with oxygen directly.

General Considerations : The oxidation process is the addition of O_2 or removal of H_2 from the substrate takes place. A substrate is oxidised if it loses hydrogen. A substrate which gives up hydrogen under suitable condition is called a "hydrogen donator" and such loss only takes place when the liberated hydrogen can be readily incorporated into another molecule called a "hydrogen acceptor" which is thus itself reduced. If the acceptor is to go on functioning, it loses its hydrogen gain but in the tissues this occurs by union of the hydrogen directly or indirectly with molecular oxygen to form water.

Chemicals concerning Tissue Respiration :

I. **Cytochrome System :** The cytochrome is a group of pigments composed of an iron-containing hæmatin compound combined with another unknown nitrogenous body, known as hæmochromogens.

In the living cells, cytochrome can be seen to undergo alternate oxidation reduction. The oxidised cytochrome gives up its oxygen to the substrate and itself becomes reduced. The reduced cytochrome takes up oxygen from outside and becomes oxidised again and in such a way cytochrome works as a catalyst. The reduction of oxidised cytochrome is helped by a dehydrogenase, which takes away hydrogen from the substrate and gives it to the oxidised cytochrome acts both as a hydrogen acceptor as well as oxygen carrier. Rapid oxidation of reduced cytochrome is helped by another oxidase known as cytochrome oxidase.

II. **Glutathione** (Glutamyl-Cysteyl-Glycine) or **G-SH :** The glutathione is a tripeptide of glycine, cysteine and glutamic acid and discovered by *F. G. Hopkins* in 1921. It can exist in the reduced sulfhydryl form and designated at G-SH. It exists in two forms such as oxidised and reduced form. The reduced form contains cystine and one molecule each of glycine and glutamic acid. The oxidised form contains cystine and two molecules each of glycine and glutamic acid. On oxidation cysteine may be converted into disulphide form of cystine.

Glutathione plays an important role in the process of tissue respiration. The oxidised glutathione takes away hydrogen from the food stuffs and thus oxidises them and it itself being reduced. Reduced glutathione is reoxidised by molecular oxygen in presence of iron and thus the cycle repeats. In the presence of traces of copper it is readily oxidised by molecular oxygen :

$$2G-SH+O_2 \longrightarrow G-S-S-G+H_2O_2$$

The oxidised form is readily reduced again in the tissues :

$$G-S-S-G+AH_2 \longrightarrow 2G-SH+A$$

III. **Warburg's yellow oxidising enzymes** (Flavin dinucleotides or flavoprotein) : The catalytically active flavoproteins or yellow enzymes can exist both in oxidised and reduced state which was first shown by *Warburg* in 1932. Chemically, it consists of flavin or Vitamin B_2. This substance in combination with protein is a flavin-adenine-dinucleotide (FAD) or alloscazine adenine dinucleotide, of which the yellow enzyme is a decomposition product. It contains no iron.

The dinuclotide can undergo reversible oxidation and reduction and so act as an oxygen carrier ; the reduced form is called leucoflavoprotein. The yellow enzyme or flavoprotein, often acts as part of a double enzyme system, the other part being a D.P.N. enzyme complex. Thus,

$$DPNH_2 + \text{Flavoprotein} \rightarrow DPN + \text{Leuco-flavoprotein.}$$

The D.P.N. so regenerated can again be reduced and so oxidised a further molecule of substrate. Meanwhile the reduced or leucoflavoprotein can be reoxidised in two steps : first a "carrier" is reduced and thereby leucoflavoprotein is oxidised ; then the reduced carrier takes up free oxygen and is converted into oxidised form. The whole cycle of changes involving D.P.N. and flavoprotein, with their specific protein partners would thus be :

$$\text{Substrate} + \text{D.P.N.} \rightarrow \text{Oxidised substrate} + \text{D.P.N.}H_2$$

$$\text{D.P.N.}H_2 + \text{Flavoprotein} \rightarrow \text{D.P.N} + \text{Leuco-flavoprotein.}$$

$$\text{Leucoflavoprotein} + \text{Carrier} \rightarrow \text{Flavoprotein} + \text{Reduced Carrier,}$$

$$\text{Reduced carrier} + O_2 \rightarrow \text{Carrier.}$$

The cytochrome C reductase acts as a donor of H_2 to the cytochrome system as shown in the following equation :

$$FPH_2 + 2\text{ cyt. }Fe^{+++} \rightarrow FP + 2\text{ cyt. }Fe^{++} + 2H^+.$$

The hydrogen ions are liberated into the cell fluids.

IV. **Xanthine Oxidase :** This enzyme was first obtained from milk by *Ball* in 1939 and its crystalline form was prepared by *Avis* in 1955. This enzyme is found chiefly in the liver and oxidises xanthine to uric acid. The xanthine oxidase contains molybdenum in addition to FAD and catalyses the oxidation of hypoxanthine to xanthine and of xanthine to uric acid.

Xanthine at first combines with water forming Xanthine hydrate. This hydrate loses two hydrogen atoms forming uric acid. The two hydrogen atoms then unite with one molecule of oxgen to form H_2O_2. The latter is broken down by the enzyme "catalase" to form water and free oxygen.

V. **Electron System :** The modern chemical theory of tissue respiration is the fundamental process involved in electron transformer.

A hydrogen atom removed during a dehydrogenation reaction undergoes "acidic ionisation", to give a proton and an electron. The proton is positively charged and electron is negatively charged particles. The term oxidation is applied to a reaction in which a substance loses electron and similarly, a gain of electrons is termed reduction. The reduced cytochrome oxidase has the unique property of transferring an electron to molecular oxygen. The protons from the initial ionisation then react with the negatively charged oxygen to give water.

Q. 12. Describe the Pulmonary Circulation.

The lung is one of the most vital organ of the body. It serves the purpose of respiration by which the deoxygenated blood converts into oxygenated one that will supply to the different extreme parts of the body for better nutrition. The lung gets double supply of blood, like the liver, through pulmonary artery and bronchial arteries and serve gaseous exchange and maintains its own nutrition.

Vascular Arrangement :

(a) **Arterial Supply :** The blood enters into the lungs through pulmonary artery and bronchial arteries which anastomose to some extent. The pulmonary artery supplies the respiratory bronchioles and their sub-divisions down to the alveoli, thie area of lung which is concerned with the gaseous exchange is drained by the pulmonary veins. The bronchial arteries are the branches of the aorta which supply the bronchi and all their sub-divisions down to the respiratory broncholes. Then there is an anastomosis between the systemic and pulmonary circulations at the level of the respiratory bronchioles. The pulmonary artery breaks up into wide arterioles and capillaries which form a fine dense network surrounding the alveoli where gaseous exchange takes place.

(b) **Venous Drainage :** The blood from the larger bronchi drains away by the bronchial veins but the blood from the smaller bronchi and the respiratory bronchioles drain into the pulmonary veins. In this way, the large pulmonary veins contain chiefly the oxygenated blood from the pulmonary circulation but a certain amount of venous blood from the bronchial circulation.

Normal Values of Pulmonary Circulation :

(1) **Minute Blood Flow :** It is the sum total of blood flow through the bronchial arteries and of right ventricular output. It is little over 4 to 5 litres.

(2) **Blood Pressure :** (i) The systolic pressure in the human pulmonary artery is a little less than 20 m.m. Hg. and the diastolic pressure is about 10 m.m. Hg. With each heart beat pressure rises by about 30 m.m. Hg. and causes pulsation in the arterial blood vessels. (ii) The pressure in the pulmonary veins is ordinarily near the zero level from -3 m m. H_2O in inspiration and to $+4$ m.m. H_2O during

expiration. (iii) The velocity of blood flow in the pulmonary artery is around 0·4 meters per second. (iv) The tone of the pulmonary arterioles is relatively low, so that a rise in the pulmonary venous pressure is readily transmitted to the arterial side.

(3) **Circulation Time** : The circulation time of the pulmonary vessels becomes 3 to 9 seconds.

Control of Pulmonary Circulation : The control of pulmonary circulation is done by nerves, hormones and by physical means.

I. **Nervous Control** : The nervous control of pulmonary circulation is done by centres, nerves and reflexes.

(a) **Centres** : The centres of pulmonary circulation are of higher and lower centres. The higher centres are of cortical and hypothalamic centres. The lower centre is situated in the medulla oblongata. (b) **Nerves** : The pulmonary vessels receive vasoconstrictor fibres through the sympathetic nervous system. The vaso-constrictor and vasodilator fibres of the vagus supply the pulmonary vessels. (c) **Reflexes** : According to *Anrep*, two mechanisms are concerned in reflex act such as reflex effect and central factor. (1) The *reflex effect* is through afferent pulmonary terminals, the vagus centre and efferent cardiac vagus fibres. (2) The *central factor* is in the mechanism leading to cardiac acceleration following inflation is due to the radiation of impulses from the respiratory centre to the cardio-inhibitory centre.

II. **Hormonal Control** : (1) *Adrenaline* : It causes constriction of the pulmonary vessels except in high dilution when it causes vasodilation. (2) *Atropine* and *Eserine* : The constriction of the pulmonary vessels is abolished by atropine and enhanced by eserine. (3) *Acetyl choline* : This is parasympatho-mimetic drug which causes dilatation of the pulmonary vessels of the dog and constriction of those of the rabbit.

III. **Physical Control** : It is done by *muscular exercise* which causes dilatation of the pulmonary vascular bed. It reduces the resistance in the pulmonary circuit inspite of a large increase in cardiac output.

Peculiarities of Pulmonary Circulation :

(1) **Carriage of Blood** : The pulmonary artery carries deoxygenated blood and pulmonary veins carry oxygented blood and two vessels have got direct anastomosis in the pulmonary bed. Therefore, lungs gets nutrition from mixed blood.

(2) **Absence of Filtration** : The filtration takes place into the tissue spaces in systemic capillaries. The filtration would cause accumulation of liquid in the lung alveoli and enhances oxygenation of blood. The colloidal osmotic pressure is much higher than the blood pressure in the pulmonary capillaries and thereby there will be no filtration in the lungs. The pulmonary congestion will increase the

local blood pressure that leads to filtration and causes oedema of the lungs.

(3) **Discrepancy of Blood Circulation :** The blood enters the lungs through pulmonary and bronchial arteries The blood is returned from the lungs through pulmonary veins (oxygenated blood) and bronchial veins (reduced blood). The venous return to the left heart would be more than the output of right heart and discrepancy of blood circulation may lead to heart failure.

(4) **Role as a Reservoir of Blood :** The pulmonary vessels are distensible and for its distensibilty, it can accommodate large amount of blood and also plays as a blood reservoir.

(5) **Double Blood Supply :** The pulmonary vascular system supply alveolar tissue whereas systemic system has to supply different types of tissues. The pulmonary vascular twig has got no well organised vasomotor control whereas systemic one has got well organised vasomotor control and because it possesses different types of tissues and maintains under different pressure gradient.

(6) **Haemodynamic Mechanism :** The pulmonary artery and vein are exposed to sub-atmospheric pressure and thereby it affects the haemodynamic of the pulmonary circulation and the haemodynamic alteration in pulmonary circulation in different phases of respiration indirectly affects the systemic circulation.

Measurement of Pulmonary Vascular Resistance :

(1) **Arterial Pressure Method** (*Allison* and *Linden*) : The pulmonary vascular resistance can only be measured by recording the flow through the pulmonary artery with simultaneous measurements of the pulmonary arterial and left atrial pressures.

(2) **Catheterisation Method** (*Dexter*, 1954) : The method of measuring pulmonary resistance is to wedge the tip of a very fine catheter passed via the venacava, the right heart and the pulmonary artery. According to *Dexter*, it allows an approximate measurement of the pulmonary capillary pressure.

Q. 13. What do you know about Asphyxia ?

Asphyxia is the condition where there will be lack of oxygen and excess of carbon dioxide in the system due to the interference of the gaseous interchange between the lung alveoli and pulmonary capillaries. It produces a series of pathological manifestations and cause death of the individual.

Causes : The important causes of asphyxia are Diphtheria, Throttling or hanging, Drowning, Tumour or Cancer of the trachea, Artificial clumping of trachea, Paralysis of the respiratory muscles and bilateral lobar pneumonia.

Important conditions of Asphyxia : The important conditions are : (1) There must be both CO_2 excess as well as O_2 lack.

(2) Animal must be intact. (3) The improper airation must be continued.

Stages of Asphyxia: Asphyxia is described into three stages, each stage showing characteristic features :

(a) **Stage of Hyperpnoea** ; In this stage there will be increased respiration which is followed by dyspnoea. The expiratory movements become more pronounced than inspiration. All these manifestations are due to the increased accumulation of the reduced haemoglobin. Towards the later part of this stage there will be unconciousness. The stage lasts for 1 minute.

(b) **Stage of Expiratory Convulsion** : In this stage, there will be convulsive counteraction of the respiratory muscles. There will also be convulsive contraction of the voluntary muscles of the body due to the stimulation of the anterior horn cells by excess of CO_2. Heart rate is high and blood pressure is also increased. This stage lasts for 1 to 2 minutes.

(c) **Stage of Exhaustion or Slow deep Inspiration** : In this stage, there will be paralysis of the respiratory centre due to the excess of CO_2 and complete lack of O_2 and so there will be respiratory failure. The cardiac control and vasomotor centre will also be inhibited by excess of CO_2 and lack of O_2. The heart continues to beat at a rate of 2 to 3 per minute after the complete stoppage of respiration and ultimatly heart rate will be stopped due to cardiac failure. Blood pressure will fall just before death. There will be dilatation of pupil. This stage lasts for 2 to 3 minutes.

Q. 14. What is Anoxia or Hypoxia ? Describe the different types of anoxia. What are the effects of Anoxia ?

The failure of tissues, for any reason, to receive an adequate supply of oxygen is called anoxia, hypoxia, oxygen lack or oxygen want. Anoxia occurs commonly and complicates many diseases as a secondary factor. It is important to obtain a clear idea of the effects of anoxia and the various condition which may produce it.

Classification of Anoxia :

I. According to *Barcroft*, anoxia has been classified into following varieties : (a) **Anoxic Type** : Defective oxygenation of the blood in the lungs. (b) **Anaemic Type** : Lower oxygen capacity of the blood. (c) **Stagnant Type** : Slowing of the movement of blood through the capillaries.

II. According to *Peters* and *Vanslyke*, a fourth type of anoxia known as **Histotoxic Type** which is caused by poisoning by the oxidative process of the tissues.

Different Types of Anoxia :

I. **Anoxic Type or Arterial hypoxia** : In this type the lack of oxygen in the tissues has been localised due to the less supply of O_2 from the atmosphere or from respiratory tracts.

Causes : (1) Low O_2 tension in the inspired air i.e. variation of the atmosphere by foreign gases, high altitudes and mountain sickness. (2) Abnormalities of the pulmonary mechanism, pneumonia, asthma, emphysema, collapse of the lung, pulmonary engorgement or oedema, obstruction of air passages, paralysis of the respiratory muscles or depression of the respiratory centre by narcotics and anaesthetics. (3) Direct communication between right and left sides of the heart through which venous blood is shortly circulated by means of shunting.

Symptoms : (1) An increase in heart rate, dyspnoea and cyanosis. (2) Mental distrurbances like exhilaration, delirium, mania or fixed ideas. (3) The tension of the blood is low and so the rate of tissue oxidation is diminished (4) There is less O_2 present in the blood so that any activity demanding a large O_2 consumption is impossible. (5) The oxygen which is present in the blood is not readily available to the tissues, owing to the low carbon dioxide tension hampering the dissociation of oxyhaemoglobin.

II. **Anaemic Type :** In this type, the tension of oxygen in the arterial blood is normal but the quantity of functioning heamoglobin is too small

Causes : The cause of anaemic type of anoxia are : (1) Acute or chronic haemorrhage or anaemia from whatever cause. (2) Poisoning by nitrites and chlorates which form stable compounds with haemoglobin.

Symptoms : (1) In the severe anaemia i.e. pernicious anaemia the total haemoglobin content is diminished and the venous blood is very reduced. (2) In poisoning with nitrites, nitric oxide haemoglobin and some methaemoglobin are formed. It causes marked cyanosis owing to the presence in the blood of the coeffee coloured compound. (3) In carbon monoxide poisoning, CO acts by displacing oxygen from its combination with haemoglobin forming a comparatively stable compound which is useless for gas carrying purposes. CO is poisonous because we are dependent on functioning haemoglobin oxygen transport.

III. **Stagnant Type or Hypokinetic Hypoxia :** In this type, the arterial blood is normal in oxygen tension and oxygen content, but it is supplied to the tissues is insufficient because of a decrease in the blood flow.

Causes : The causes of stagnant type of anoxia are congestive heart failure, haemorrhage, obstruction of the venous return from a part of local anoxia and surgical shock.

Symptoms : (1) The tension of the O_2 in the blood is normal, but the amount reaching the tissues is inadequate. (2) The rate of tissue oxidation is normal, because O_2 supplied at high pressure. (3) As the blood circulates more slowly in the tissues there is more time available for reduction of oxyhaemoglobin. (4) The impaired circulation causes CO_2 accumulation in tissues, which facilitates the giving off of oxygen.

IV. **Histotoxic Type :** In this type, the tissue cells are poisoned and cannot make effective use of oxygen supplied to them.

Causes : The causes of histotoxic type of anoxia are : (1) In poisoning with cyanide, it interferes with tissue oxidation. (2) By paralysing cytochrome oxidase. (3) Narcotics also depressed tissue oxidation by interferring with dehydrogenase systems.

Symptoms : (1) Loss of capacity of the tissue cells to utilise oxygen. (2) The oxygen supply becomes normal but the cells fail to use it paralysing the mechanism of tissue oxidation. (3) The cyanide and narcotics produce this type of anoxia by paralysing the mechanism of tissue oxidation.

Effects of Anoxia on Different Systems : The effects of anoxia varies according to the severity and rate of production of O_2 lack. When O_2 lack is very severe, sudden unconsciousness occurs. If the anoxia is produced gradually, the effects will be the following :

(1) **Digestive System :** There is loss of appetite, nausea, vomiting, diarrhoea and absence of desire for said food.

(2) **Circulatory System :** (i) The force and frequency of the heart increases at first and later on force dies down and frequency increases more. (ii) The minute output and blood pressure increase due to lack of oxygen which stimulates the cardio-acceleratory centre and vasomotor centre.

(3) **Respiratory System :** The breathing at first becomes more shallow and periodic in character, then increases in rate and cyanosis develops.

(4) **Nervous System :** (i) The nervous disturbances appear. The person behaves just like a drunkard. He becomes quarrelsome and laughing. (ii) There is headache, depression, drowsiness or excitement, loss of self-control, loss of memory and loss of judgment. (iii) Understanding is impaired more than any sensations and appreciation of time is altered. The failure of judgement and inability to properly co-ordinate mucular movements appear at a much earlier stage and then loss of consciousness (iv) There is great muscular weakness, inco-ordinated movements and easy fatigue. There will be occurrence of sudden paralysis of upper or lower limbs.

Q. 15. Describe the salient features of early and late changes in the body during Acclimatization (Ascent of high altitude).

The physiology of respiration at higher altitude is particularly interesting in connection with exploids in mountaineering or aviation, The chief difference between the two being that in the former that great physical exertion must be coupled with the drawback of reduced air pressure in an adverse climate, while in the latter there is a drawback of rapid reduction of pressure and the onset of symptoms correspondingly sudden A good deal of investigation has been carried out for purpose of studying the phenomenon involved in the response of an acclimatization to lower air pressure during both air craft and mountain ascents.

Features of Acclimatization :

I. Early or Immediate Changes :

(a) **Changes in Respiration :** (1) The greater deminution of the partial pressure of O_2 than that of CO_2 in the alveolar air. (2) The CO_2 pressure does fall somewhat and this is due to increase pulmonary ventilation. (3) The total volume of lungs increases and thereby lung can hold more air. (4) The increased breathing is a consequence of the reduced O_2 pressure and provides an increased lung surface.

(b) **Changes in Urine :** (1) An increased excretion of CO_2 causing increasing in blood alkalinity and to the excretion of an alkaline urine to combat alkalosis. (2) Urea content is more and ammonium salts less and thereby ammonia will excrete out along with urine.

(c) **Changes in Blood :** (1) As an immediate effect of change to a region of low atmospheric pressure there is an apparent increase of blood corpuscles. due to the a concentration of blood and a deminution of its plasma and perhaps also to a contraction of spleen. (2) Blood volume increases, haemoglobin content of blood rises and therefore the oxygen capacity is raised. (3) There is a tendency towards alkalosis which is compensated by excretion of alkaline urine.

(d) **Changes in Circulation :** (1) In higher ascent a deficient oxygenation of the blood may be localised. In this case both the stroke volume of heart and pulse rate increase in early stage of O_2 deprivation (2) During failure of circulation there will be severe mountain sickness and it is closely resemble the symptoms to be produced by heart failure. (3) The O_2 starvation of the brain produces failure of judgement, inability to carry out or to co-ordinate muscular movements properly and then loss of consiousness. (4) There is the increase of heart rate, minute output and blood pressure. (5) The vaso-motor stimulation leads to constriction of blood vessels that will lead to increase rate of circulation.

II. Late or Delayed Changes :

(1) The change in the bone marrow takes place, Due to lack of O_2, the red bone marrow proliferates. The yellow bone marrow may be transformed into red bone marrow, (2) The vital capacity of lungs increases in those people who live at higher altitude for a long period of time.

Q. 16. What do you mean by Mountain Sickness ? Describe the signs and symptoms.

When a person ascends gradually and slowly upto 14,000 ft. certain unpleasant signs and symtoms appear due to derangement of different systems, is known as *Mountain sickness* or *Altitude sickness.*

Sings and Symptoms :

(1) **Digestive System :** There is loss of appetite, nausea and vomiting.

(2) **Circulatory System :** The force and frequency of the heart increase. The minute output and blood pressure rise due to lack of oxygen which stimulates the cardio-acceleratory and vasomotor centres.

(3) **Respiratory System :** There will be slight breathlessness cauing difficulty in breathing and cheyne-stokes type of breathing also occur. The pain in the chest may occur.

(4) **Nervous System :** The nervous disturbances arise. The person becomes quarrelsome and laughing. There is headache, nausea. vomiting, depression, drowsiness, loss of selfcontrol, loss of memory, loss of power of judgement,. extreme degree of muscular weakness and inco-ordination of muscular mevements.

Q. 17. Describe the different methods of Artificial Respiration.

It has always been man's desire to revive those apparently dead. By his efforts and hopes of success he has been instrumental in the saving of countless lives that otherwise would have lost. In ancient times man's efforts were directed to attempts restoration of the apparently lifeless. From early time down to the present, there has been constant effort to improve on existing methods or discover new means of accomplishing this humanitarian service.

Cause : The artificial respiration is adapted in cases of suspended respirations due to drowning, electric shock, suffocation, carbon monoxide poisoning or during anaesthesia.

Methods of Artificial Respiration :

[A] **In the New-Born Baby :** The artificial respiration is necessary for the new born babies for their delayed respiration. The different methods in such cases are the following : (1) Holding the baby upside down for flowing more blood enter into the brain. (2) Patting on the back region of the newborn baby and respiration starts by reflex stimulation. (3) The newly born child is alternately putting in warm and cold water and respiration begins by reflex mechanism. (4) Forcibly blowing of air through the mouth of the new-bron child after closing its nostrils.

[B] **In the Adult Individual :**

I. **Emergency or Manual Methods :**

(a) **Holger Nielsen's Arm-Lift-Back Pressure Method :** The subject lies prone, with this arms overhead and elbows fixed, so that one hand rests on the other, the head is turned to one side, the cheek resting on the uppermost hand. The operator kneels on his left knee at the subject's head, with his right foot near the subject's left elbows, the operator rocks backwards, raising the subject's arms until a resistance is felt, the arms are then dropped. The operator then lays his hands just below the scapulae and with straight arms rocks forwards until they are vertical, keeping a steady pressure on the subject's chest. The movements of lifting and compression, each of 2½ seconds, should be repeated twelve times a minute.

(b) **Mouth to mouth or Expired Air Method :** The operator takes a deep breath and applies his wide open mouth to the subject by occluding his nose and blows air into the subject's lungs. During expiration, the operator withdraws his head so as to enable him to take in another deep breath and to allow expulsion of the subject's lungs by means of the elastic recoil of his lungs and chest wall. The cycle is then repeated, 12 to 15 times per minute.

(c) **Eve's Rocking Method :** The patient is placed in the prone position on a stretcher, which it rocked on a pivot, like a see-saw, 45 degrees up and down 12 to 15 times a minute. When the head is downwards, the weight of the abdominal viscera pushes the diaphragm up and in the feet-down position the diaphragm descends.

(d) **Sylvester's Method :** The subject is placed in supine position. The operator kneels at the head end and holds the two arms of the subject. The operator then raises the subject's hand above his head. He then folds the hands back upon the chest and compresses the chest wall at the same time. In this way, the thoracic cavity is alternately increased and decreased and thus air is drawing in and pushing out from the lungs. This type of artificial respiration is most commonly used in the operation theatre on in any types of accidents.

(e) **Schafer's Prone Pressure Method** : The subject is laid on the ground in the prone position and a thick folded garment is placed underneath the chest and epigastrium. The head is turned to one side and the arms are extended. The two hands are placed on the two sides of the lower part of the chest. The operator then gently throws the weight of his body forward to bear upon his own arms and thus press upon the loins of the subject and directly on the abdominal contents. The diaphragm is pushed up into the chest and forced out of the lungs due to increased intra-abdominal pressure. After this the operator releases the pressure and comes back to his original erect position. The abdominal pressure falls, diaphragm goes down and air is sucked in. This is repeated rhythmically at the rate of 12 to 15 times a minute until normal respiration begins. A half an hour or more time may be required for this purposes.

II. **Mechanical Methods** (Inflation or Instrumental method) :

(a) **Drinker's Iron lung chamber Method :** The patient is inside an air-tight cabinet known as "Iron-lung respirator" with the head and neck outside. The alternate negative and positive pressures are produced in the cabinet by means of electrically driven pumps. The effects is to produce movements of the chest wall resembling those of inspiration and expiration. This method is very useful in cases of morphine poisoning, in paralysis of the respiratory muscles and in poliomyelitis etc.

(b) **Bragg-Paul Pulsator Method** : It is a rubber air bag which is wrapped round the chest wall. It is alternately inflated and deflated by means of pump worked by a motor. Expiration is an active movement in this process and when the pressure is reduced, the chest enlarges passively by its own elasticity and air is sucked in.

III. **Abdominal Methods** :

(a) **Dewell Gann's Apparatus** : *Gann* developed an apparatus that consists of two rubber suction cups, each with valves in the cups to regulate pressure. These cup applicators were attached to an adjustable frame and applied to the anterior surface of the chest or abdomen. A binder held the applicators to the body. Pressure on the handles of the cups depressed them so that they adhered closely to the skin. By alternating pressure and release, he was able to produce a stimulated respiratory act.

(b) **Swan's Respirator** : *Swan* developed a single cup respirator, hand-operated, which was attached to the chest or abdomen. This was held firmly adherent to the body and permitted the pressure being exerted to induce respiration without apparent harm to the patient.

IV. **Medical Methods** : The different drugs help in the process of artificial respiration. Spirits of ammonia by inhalation is commonly used in conjunction with the manual methods of artificial respiration by the layman. Bleeding by opening of a vein was common in the early days. Dilatation of the anal sphincter muscle stimulates respiration and is still used. Inhalations of oxygen and carbon dioxide as recommended by *Haggard* and *Henderson* have proved of great value.

V. **Surgical Methods** : This is an operative procedure used only during an operation in which the body cavities have been opened and the heart is accessible for direct manipulation. During ceasation of respiration, the direct massage of the heart should be done. If the incision is in the abdominal cavity, the surgeon may attempt massage of the heart through the diaphragm.

Q. 18. What do you know about Vital Capacity ? How can you measure the vital capacity of an individual ?

The average man after he has completed an ordinary expiration can inhale by making the deepest inspiration of which he is capable is known as complemental air that becomes nearly about 2,000 ml. If starting again from a position of rest, after making a forcible expiratory effort, the air that expelled is known as supplemental air that becomes nearly about 1500 ml. So the volumes of the complemental and supplemental air i.e. the total amount of air which can be exhaled after a maximum inspiration is called *vital capacity* and is on an average 4,000 ml It can be measured by an instrument known as *Spirometer* and the record is known as *Spirogram.*

Factors influencing Vital Capacity : The vital capacity is influenced by the following factors :

(1) **Size :** The vital capacity is directly proportional to the size of the individual and to the degree of respiratory exercise undergone by the subject.

(2) **Sex :** It is less in females than males.

(3) **Surface Area :** In males, it is 2·6 liters per square metre of body surface and 2·0 litres per square metre of body surface in females.

(4) **Posture :** The vital capacity is altered due to changed posture and is greater in the upright position.

(5) **Disease :** The vital capacity is reduced in many diseases such as pulmonory tuberculosis, exophthalmic goitre, pleural effusion, heart failure, pneumonia, pneumothorax, emphysema of the lungs, etc.

Measurement of Vital Capacity in Man : The spirometer is an instrument by which the vital capacity of an individual is measured.

Principle : The vital capacity is the volume of air that can be breathed out by forced expiration after taking deep inspiration. It is the sum total of tidal air, complemental air and supplemental air. It is about 3500 ml. Athelets show higher figure. Respiratory efficiency is judged by the vital capacity.

Parts of the Apparatus : The apparatus spirometer consists of : (1) The inner and outer cylinders with wide bores. (2) Graduated disc with a pointer, (3) A pulley. (4) Weight attached to the thread so that it may hang over the pulley. (5) Rubber tubing and (5) Three levelling screws.

Procedure : The outer drum contains water upon which the inner drum is inverted and which is attached to the pulley by a string. (2) As soon as the expired air is forced into the spirometer by the rubber tubing, the column of air enclosed within the inverted cylinder over water the inverted cylinder upwards. (3) At a point it stands after the forced expiration. That point read from the graduated disc gives the measure of the vital capacity. (4) The inner drum attached to the pulley is such that from the upward position it never falls until it is forced downwards. The graduation in the disc is in ml.

Q. 19. What is Cyanosis ? Describe the causes of Cyanosis.

Cyanosis may be defined as the diffuse, dusky or bluish colour imparted to the skin, specially of the lips, ears, hands and feet and of the nails by the pressure in the blood of the superficial capillaries of reduced haemoglobin above a certain definite amount, resulting from inadequate oxygenation of the arterial blood or from the utilization of an undue proportion of the O_2 of the blood during its transit through the capillary circulation The blue colour of the skin depends fundamentally upon the absolute amount of reduced haemoglobin in the capillary blood and not upon the relative proportions of reduced and oxyhaemoglobin.

Causes : (1) Incomplete oxygenation of blood in the lungs such as in cardiac failure, congential heart disease, obstruction in the trachea and bronchous, carbon monoxide poisoning etc. (2) Abnormal admixture of venous and arterial blood in certain congenital heart diseases due to presence of patent inter-ventricular septum and the patent foramen ovale. (3) Impaired diffusion across the alveolar membrane. (4) Alteration of the haemoglobin of the blood in certain poisonings and coal tar products etc. (5) Abnormal reduction of Haemoglobin in the systemic capillaries.

Q. 20. What do you know about Caisson Disease or Decompression Sickness or Dysbarism. (Compressed Air Sickness, Low altitude and high atmospheric pressure).

A caisson is a steel chamber filled with compressed air and sunk under water, generally to carry out operations in beds of rivers. It occurs in deep sea divers or workers in caissons when they pass too quickly from the high pressure in which they have beenconfined to the ordinary pressure of the atmosphere At first there is little discomfort except temporary giddiness and noises in the ears. Breathing and pulse rate become slowed and there is frequency of micturition.

Symptoms : These set in immediately or after some hours. The symptoms of caisson disease are the following : There is a pain in the muscles and joints and in the severe cases there will be paraplegia of the legs, dyspnoea, vomiting and circulatory failure. (2) Low pulse rate, blood pressure falls, cyanosis present and there may be faintness or convulsions ending in death. (3) There may be extensive capillary haemorrhage and in extreme instances, frothing of the blood may interfere with cardiac action and with the flow of blood in the blood vessels (4) Small running pulse showing circulatory failure. (5) There will be paralysis of the legs.

Cause: These symptoms are produced due to the following causes: (1) The bubbles of the gas, mainly composed of nitrogen, oxygen and carbon dioxide, from when the atmospheric pressure is lowered too rapidly. (2) Nitrogen diffuses less readily than either of the other gasses and is thus less readily eliminated to the lungs. (3) The bubbles act usually as emboli lodge such as in lungs, brain, heart, anterior or posterior nerve roots etc.

Q. 21. What is Cheyne-Stokes Breathing (Periodic breathing) ? How it occurs ?

The chenye-stokes breathing is one of the most common type of periodic breathing in which the individual respirations are small and slow to start with but gradually increase in depth and rate to a maximum and then subsiding again, finally cease for a time. The hyperpneic and apneic phases last each for about 30 seconds. A tendency of this type of breathing is not uncommonly shown by healthy infants and occassionally by normal adults during sleep.

Occurrence : The cheyne-stokes breathing is primarily dependent on anoxia but it generally occurs in : (1) Raised intra-cranial pressure from cerebral tumour, cerebral haemorrhage, meningitis, cerebral abscess. (2) In advanced renal and cardiac diseases and in asthma. (3) In severe pneumonia and in morphine and chloral poisoning. (4) In circulatory failure, pernicious anaemia and high altitudes.

Q. 22. What is Respiratory Quotient (R. Q.) ? What are the factors affecting respiratory Quotient ?

The respiratory quotient is the ratio between the volume of carbon dioxide evolved and the volume of oxygen absorbed during a given time. The normal R. Q. in a healthy adult with a mixed diet is 0·85.

Factors affecting Respiratory Quotient :

(a) **Role of Diet :** (1) On a mixed diet, R. Q. is 0·85. (2) On purely carbohydrate diet, R. Q. is 1. (3) On purely protein diet R. Q. is 0·8. (4) On purely fat diet, R Q. is 0·7.

(b) **In Hydrogen-ion-Concentration :** (1) In acidaemia, R Q. rises due to hyperpnoea. (2) In alkalimia, R. Q falls as the breathing is depressed

(c) **During Muscular Exercise :** (1) During exercise R. Q. rises above one, due to the breakdown of plasma bicarbonate by lactic acid, liberating large volume of CO_2 which are eliminated from the lungs. (2) During recovery from violent exercise, R.Q. falls below normal due to CO_2 being retained in the blood to reform bicarbonates.

(d) **High Altitude :** R.Q. increases due to increased pulmonary ventilation caused by aneoxia.

(e) **Starvation :** 1) R.Q. is about one due to the combustion of carbohydrate for one or two days. (2) R.Q. falls below normal because the body is living on its own fats and proteins in the second and final stages of initiation.

(f) **Diabetes :** R.Q. falls below normal because body is burning only by protein and fats.

(g) **Voluntary Hyperpnoea :** R.Q. increases considerably above one, due to the elimination of large amount of CO_2 without increase in O_2 consumption.

Q. 23. Describe briefly the effects of Respiration on Circulation.

The general process of respiration and its mechanism has got effect on circulation. The principal effects of respiration on circulation are venous return, cardiac output, heart rate and blood pressure.

I. **Venous Return:** It is a process by which venous blood is returned to the heart.

(a) *During Inspiration:* Due to the descent of the diaphragm, the intra-thoracic pressure becomes more negative and intra-abdominal pressure is more increased. The negative intra-thoracic pressure distends the thin-walled auricles and veins and the increased intra-abdominal pressure squeezes the veins of the abdomen and sends blood upwards into the thorax. The suction pressure of the thorax sucks more blood into the already distended right auricle. It is known as the respiratory pump.

(b) *During Expiration:* The opposite effect is now produced and the venous return to the heart is diminished.

II. **Cardiac Output:** It is an output of blood from either of the ventricles due to the systolic condition of the heart.

(a) *During Inspiration* · The increased venous return would tend to increase the cardiac output. The blood capacity of the lungs, is increased owing to stretching of the capillaries during expansion of the lungs, blood is held back there and consequently the flow into the left ventricle is diminished causing diminished cardiac output.

(b) *During Expiration:* The diminished venous return would tend to diminish the cardiac output. But the pulmonary capillaries are compressed due to elastic recoil of the lungs and send the blood, hold back there during inspiration, into the left ventricle, along with the blood received during expiration. Thus the cardiac output will increase.

III. **Heart Rate:** The normal heart rate has got an effect on respiration.

(a) *During Inspiration:* The increased venous return will cause increased venous pressure in the right auricle. The direct irradiation from the respiratory centre causes increased heart rate.

(b) *During Expiration:* The increased vagal tone slows the heart resulting diminished venous return. The respiratory variation in heart rate during inspiration and expiration are very seldom noticed in adults during quiet breathing.

IV. **Blood Pressure:** It is the lateral pressure of blood on the wall of the artery due to the systolic condition of the heart.

(a) *During Inspiration:* Due to irradiation from the respiratory centre, vasomotor centre is stimulated towards the end of inspiration causing increased arteriolar tone and the rate of the heart and blood pressure rise.

(b) *During Expiration:* It causes a fall of blood pressure. The pulmonary bed changes raise blood pressure during expiration while the alterations in venous return and heart rate tend to produce exactly the reverse effects.

Q 24. Write Short Notes On : Tidal air, supplemental air, complemental air, Residual air, Dead space, Intra-pulmonary pressure, Intra-pleural pressure, Intra-thoracic pressure, Dyspnoea, Apnoea, Compsition of Inspired air, Expired air and Alveolar air, Carbonic anhydrase, Alkali reserve and Respiratory pigments.

Tidal Air : It is the amount of air which is breathed in or breathed out during normal respiration. The amount is near about 500 ml.

Supplemental (Reserve) Air : It is the amount of air which can be forcibly expelled out after normal expiration and the amount is nearly about 1500 ml.

Complemental Air : The amount of air which can be breathed in by forcible inspiration after a normal inspiration. The amount is nearly about to 200 ml.

Residual Air : The amount of air which is left in the lungs after the most forcible expiration. The amount is nearly about 1000 ml.

Dead Space : It is the amount of air present in the bronchial tree like nasopharynx, trachea, bronchi and broncheoles. It amounts to about 150 ml.

Intra-pulmonary Pressure : It is the pressure within the lung alveoli and the pressure is 760 m.m. Hg. i.e. equal to the atmospheric pressure.

Intra-pleural Pressure : It is the pressure within the pleural sac and it is 5 m.m. Hg. less than the atmospheric pressure Due to the negative intra-pleural pressure, the lung alveoli can remain in a distended condition. If the air is introduced into the pleural cavity and when the pressure becomes equal to the atmospheric pressure or more than atmospheric pressure, the lung will collapse.

Intra-thoracic Pressure : It is the pressure within the thorax and it is also less than one atmosphere. It is always negative and this pressure helps the venous return to the heart, return of lymph via thoracic duct and the act of swallowing.

Dyspnoea : It is a laboured breathing done by active and forced expirations and there is consciousness of the necessity for increased respiratory effort. The causes of dyspnoea are : (1) Increased B.M.R in exophthalmic goitre and severe muscular exercise. (2) Alteration in acid-base equilibrium by nephritis, uraemia and diabetes (3) Anoxia and heart disease (4) Mechanical obstruction to the respiratory movements as in asthma, emphysema, pneumothorax, pleuresy, thoracic tumour, obstruction to air passages, renal disease, cardiac disorders and anaemia.

Apnoea : It is a condition of temporary stoppage of rhythmic breathing due to lack of stimulation of the respiratory centre. The causes of apnoea are: (1) Increased pulmonary ventilation. (2) Artificial stimulation of the central end of the cut vagus. (3) Injection of adrenaline. The different types of apnoea are the following:

(1) *Vagal or Inhibitory apnoea*: The stimulation of the nerve will cause inhibition of the respiratory centre.

(2) *Adrenaline apnoea*: The injection of adrenaline will raise the blood prssure which will stimulate the sino-aortic nerve and these nerves will inhibit the respiratory centre and so there is temporary stoppage of breathing.

(3) *Deglutition apnoea*: During swallowing of the food, the glossopharyngeal nerve will get stimulated which will inhibit the respiratory centre and so there will be temporary stoppage of breathing.

(4) *Voluntary apnoea*: During the rapid voluntary breathing there will be increased washing out of CO_2 which will cause temporary inhibition of the respiratory centre and there will be temporary stoppage of breating.

(5) *Chemical apnoea or Apnoea Vera*: The increased pulmonary ventilation lowers the pressure of CO_2 in the alveolar air that fails to stimulate the respiratory centre and the rhythmic discharge of respiration ceases temporarily.

Composition oi Inspired Air, Expired Air and Alveolar Air :

Constituents	Inspired Air	Expired Air.	Alveolar Air
(1) Nitrogen	79%	80%	79·7%
(2) Oxygen	20·96%	16%	14·8%
(3) Carbon dioxide ...	0·04%	4%	5·5%
(4) Water Vapour ...	Variable	Saturated	Variable

Carbonic anhydrase: It is a colourless zinc-protein-enzyme. Zinc acts as a co-enzyme and enhances the action of the specific enzyme-protein in the tissues which is inhibited by cyanide.

The red blood cell contain a rich supply of carbonic anhydrase. Gastric mucosa and pancreas contain more. The carbonic anhydrase helps in the secretion of HCl and bicarbonate. This enzyme is present in traces in the sperm, muscle, liver, spleen and the central nervous system. It is absent from lungs, heart, kidneys, gall-bladder, intestines peripheral nervous tissue, milk, bile and urine.

Alkali Reserve : It is the volume of CO_2 which is expelled by acid from 100 volumes of plasma which has previously being equilibrated with alveolar air containing CO_2 at 40 m.m. Hg. tension, CO_2 in physical solution being deduced.

Respiratory Pigments : These are iron-containing substances which easily combine with oxygen to form the easily dissociable compounds which play an important role in the respiratory interchange of gases in the lungs and the tissues. The respiratory pigments are haemoglobin, cytochrome ('a', 'b' and 'c'), cytochrome oxidase and catalase.

There are other substances which also act as respiratory pigments by influencing oxidation-reduction reactions in the tissue cells and respiratory interchange of gases in the lungs and tissues. They are glutathione, ascorbic acid and flavoprotein or yellow enzyme The glutathione and ascorbic acid are the non-enzymic mediators. The flavoprotein contains riboflavin which is regarded as an oxidative enzyme and acts as an intermediate in oxygen transport.

Hyperpnoea : It is an increase is the quantity of air breathed in per minute. The causes of hyperpnoea are : (1) Voluntary. (2) Impulses from the hypothalamus (3) Impulses from the cerebral cortex to the respiratory centres. (4) Stimulation of nerves of general sensation in the skin like pain, heat, cold, etc (5) Conditions demanding more oxygen supply and production of carbon-dioxide, for instance muscular exercise.

Acapnia : It is a condition of the diminution of carbon-dioxide tension in the blood and alveolar air which is the causation of mountain sickness. It produces rapid heart failure associated with dilated heart, cyanosis, muscular weakness, vomiting, mental disturbances, inco-ordination, delirium, etc.

Orthopnoea : It is a condition of occurrence of dyspnoea at rest in severe congestive cardiac failure. In this condition, the patient feels more comportable in the sitting position than when lying down. The patient passes the whole day and night, being propped up by pillows or sleeping on an orthopnoeic table.

CHAPTER NINE

EXCRETORY SYSTEM

Introduction : Excretion is a physico-chemical process by means of which an unwanted harmful nitrogenous waste products formed during catabolism is to be drained out of the body to the exterior. The organs concrened are known as excretory organs and the system is known as excretory system. The excretory products or excreta are drained out through kidneys, skin, lungs, gastro-intestinal tract, salivary glands and liver. The excretory materials are of three categories like liquid, heavy metals and volatile products. The soluble, non-irritant substances and water are mainly excreted through the kidneys and to a lesser extent through the skin. The volatile substances like carbon dioxide, ammonia, alcohol, ketone bodies, etc. are excreted through the lungs, heavy metals are excreted through the gastro-intestinal tract and fats and fat derivatives are excreted out through the skin as sebum and along with bile from the liver. Kidney is the main excretory organ among others. In consists of ureters, urinary bladder and urethra. Kidney helps in the formation of urine after filtering blood. The ureter helps in the transport of urine from kidneys to the urinary bladder. The urinary bladder helps for reservoir of urine. The urethra helps for passing of urine from the urinary bladder to the external enviornment through external excretory aperture. The secretion, formation and elimination of urine from the body serves the vital functions and maintains bodily homeostasis.

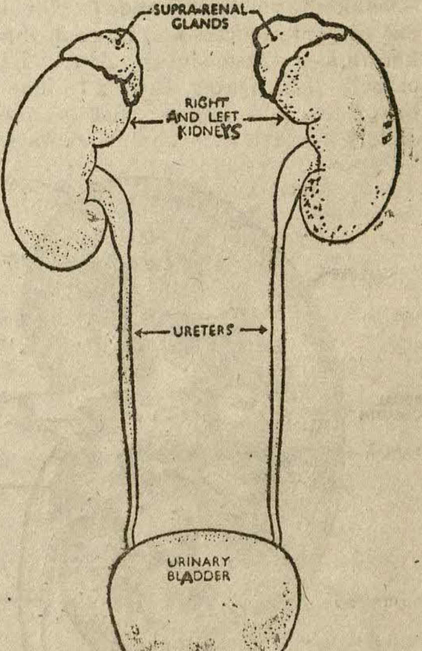


Fig. 26. Diagrammatic representation of the Excretory Apparatus showing kidney, ureter, urinary bladder, etc.

Q. 1. Describe the structure and function Kidney.

The kidney is the most important excretory organ of the human body situated in the posterior abdominal cavity, one on each side of the vertebral column and behind the parietal peritoneum on the upper part of the posterior wall of the abdomen.

Anatomical Considerations : The kidneys are two in number and situated in the posterior abdominal cavity. These are soft and ovoid in outline with one border concave These are 11 cm. in length, 6 cm. in breadth and 3 cm. in thickness. The left kidney is higher and reaches upto lower border of 11th. rib. It is longer, narrower and closer in midline than the right one. The long axis of the kidney is directed downwards and laterally and transverse axis—backwards and laterally. In males, the weight of each kidney is 125 to 170 gms and 115 to 155 gms. in females.

Naked Eye Appearance : The kidney after longitudinal section has got outer cortex and inner-medulla and there is a zone in between known as Juxta-medullary Zone. Each kidney is invested by a fibrous capsule (a) **Outer Cortex :** The cortical substance is reddish-brown in colour and soft and granular in consistency. It lies immediately beneath the fibrous capsule. This area contains superficial cortical glomeruli, medullary rays, interlobular artery and vein, stellate artery and vein, peritubular capillary plexus, subcapsular peritubular capillary plexus etc. (b) **Inner Medulla :** This area contains renal pyramid, cortical arch, renal columns, interlobar artery and vein, archifrom artery and vien, vasa recti, medullary rays, Henle's loop, distal convoluted tubule, collecting tubule, duct of Billini, calyces mazore, calyces minore, etc. (c) **Juxta medullary Zone :** This area is formed by the junction of outer cortex and inner medulla. The nephron of this area forms juxta-medullary glomerulus which has got afferent and efferent renal arterioles having the same calibre. The nephron of this area constitutes "*Juxta glomerular Apparatus*" which secretes *renin* during emergency.

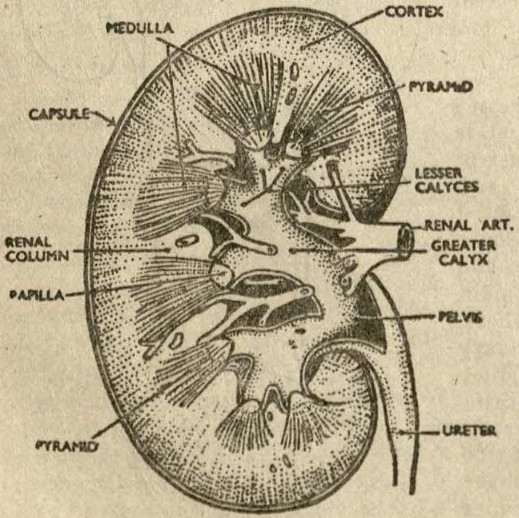


Fig. 27. Diagrammatic representation of the coronal section through the Kidney showing its different structures.

Functions of Kidney : (1) Kidney helps in the excretion of non-threshold substances i.e. metabolites which accumulate in the blood by the oxidation of the different food stuffs. (2) It helps in the excretion of drugs which are introduced in the body orally or parenterally. (3) It helps in the excretion of toxins which are introduced in the body or which are produced within the body from the bacteria in and then they protect the body from the injurious effects of toxins. (4) It helps in the reabsorption of threshold substances which are filtered through the glomerulus and therefore maintains the normal concentration of blood plasma. (5) It helps in the reabsorption of water from the renal tubules and also prevents the filtration of the colloids which take part in the maintenance of normal osmotic pressure of the blood and thereby regulates the water balance of the body. (6) It mainiains the pH of the blood It maintains the acid-base balance by directly excereting out the acids or alkali, by phosphate mechanism and by ammonia mechanism. (7) It helps in detoxicating function. The benzoic acid which is a toxic product conjugates with amino-acid glycine in the tubular epithelial cells to give rise to a non-toxic products such as hippuric acid which will be excreted out with the urine. (8) The Juxta glomerular apparatus of the kidney secretes "*Renin*". during ischaemic condition of the kidney which will convert the plasma protein. The hypertensinogen converts into hypertensin which will constrict the blood vessels to raise the blood pressure. (9) The renal tubule will manufacture a local hormone called "Erythropoietin" in lack of oxygen which will stimulate Erythropoiesis in the red bone marrow. (10) It maintains the constant blood volume by eliminating the excess water with the urine. (11) It regulates the optimum concentration of the different constituents of the blood. (12) It manufactures certain new substances like ammonia, hippuric acid, benzoic acid and inorganic phosphates.

Q. 2. Describe the structure and function of a Nephron.

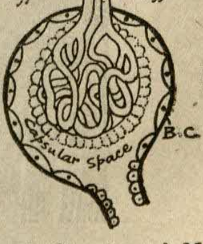


Fig. 28. Structure of Malpighian Corpuscle. Aff. A—Afferent Areriole. Eff. A—Efferent Arteriole. B. C.—Bowman's Capsule.

The nephron is the structural, functional and secretory unit of the kidney. There are two millions of nephrons in both the kidneys and therefore each kidney contains a million of nephrons. Out of this, 50% is normally functionating in the human system.

Structure of Nephron: The nephron is made up of Malpighian Corpuscle or Renal Corpuscle and Renal tubules.

A. **Malpighian Corpuscle**: It consists of Glomerulus and Bowmans's capsule. (a) **Glomerulus**: It is nothing but a tuft of capillaries derived from afferent renal arteriole. These capillaries are lined by single layer of endothelial cells and they never anastomose with each other. The capillary tuft after breaking up into an intemate meshwork is leading into an efferent arteriole. (b) **Bowman's Capsule:** It is the blind end of the Renal tubule and is lined by flattened epithelial cells. The Bowman's capsule forms a capsule around glomerulus or it invaginates the glomerulus. It consists of two layers namely visceral and parietal. The visceral layer being intemately adherent to the wall of the capillary tuft. The parietal layer on the other hand is separated from it by a potential space which is the lumen of the capsule where after filtration, filtrate collects and drops into the neck of the capsule and then pass into the proximal convoluted tubule.

B. **Renal Tubules** : The human renal tubule is about 3·0 c m. long, 20-60 microns wide and the total length of the tubules is about 40 miles. The different parts of the renal tubule are described as follows :

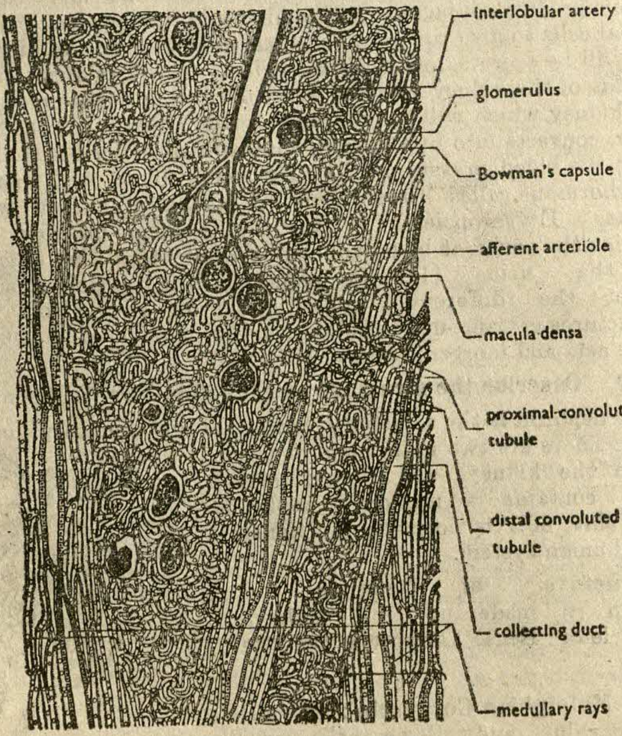


Fig. 29. Diagrammatic representation of the Histology of thr kidney showing its different structures.

(a) **Neck of the Tubule** : The tubules start from the constricted part of the Bowman's capsule which is known as neck of the tubule.

(b) **Proximal or First Convoluted Tubule :** It is a tortuous tube about 14 m.m. long It is lined by single layer of cubical cell. The mitochondria or the granules are arranged perpendicularly and parallel to each other giving the appearance of rodded, brush or bristle-bordered. The epithelium due to the presence of delicate vertical striations at their free border These striations are due to the parallel arrangement of the granules or due to the invagination of the surface membrane of the epithelial cells. It will greatly increase the surface area and therefore maximum reabsorption of the glomerular filtrate will take place from this part of the kidney tubule.

(c) **Descending limb of Henle :** The proximal convoluted tubule leads into the descending limb of Henle. It is diminished into proximal 4/5 th part and distal 1/5 th part. The proximal four-fifth part of the limb is lined by cubical epithelial cells and the distal one-fifth part of the limb is lined by flattened epithelial cells.

(d) **Loop of Henle :** The descending limb of Henle gradually narrows down and forms a horizontal U-shaped loop called the loop of Henle. It is lined by flattened epithelial cells. In the superficial nephrons, the loop is very short and dips only slightly into the medulla

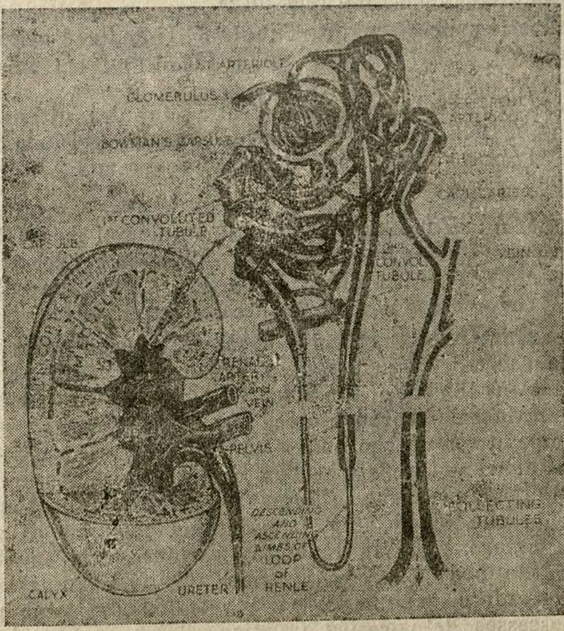


Fig. 30. Diagrammatic representation of a Nephron showing is different structural arrangement.

while in juxtamedullary nephrons, the loop is of considerable length and passes deep into the medulla.

(e) **Ascending limb of Henle :** The loop of Henle gradually widens up and leads into a wide calibered ascending limb. This is lined by single layer of cubical epithelial cells without any brush border. The average length is 20 m.m.

(f) **Distal or Second Convoluted Tubule :** The ascending limb of Henle leads into the distal convoluted tubule. It is lined by single layer of cubical epithelial cell. It has got no brush-bordered epithelium. At this particular site of contact, we find the following peculiarities : On the arteriolar side, the tunica interna is lost and flat cells of an epitheloid type cluster. These are *myoepitheloid cells of Zeimmermann*. On the arteriolar side, the cubical epithelial cells have also become flattened out and crowded compactly with very prominent nuclei. They are called as *Macula densa*. This important site is richly innervated by nerve fibres and is said to regulate the production of a hormone known as *Renin* which plays an important role in the regulation of blood pressure and as well as for the general circulation. This is called *Juxta-glomerular apparatus*.

(g) **Collecting or Straight Tubule :** It is lined by single layer of pale cuboidal cells. Several collecting tubules from different nephrons.

(h) **Duct of Bellini :** All the collecting tubules ultimately open into the duct of Bellini which is lined by columnar epitheloid cells and that ultimately opens at the apex of the renal pyramid.

Functions of Nephron :

I. **Glomerular Functions :** The glomerulus of the nephron helps in the formation of urine by either ultra-filtration or secretion or by both. There is effective filtration pressure in glomerulus which will filter all the non-colloidal substances of blood plasma.

II. **Tubular Functions :** (1) In the formation of urine, all the nitrogenous excretory products are expelled out through the urine. (2) It maintains the pH of the blood. (3) Blood volume and water balance are maintained through urine formation. (4) It regulates the normal temperature of the body. (5) It maintains the osmotic pressure in the blood and regulates the osmotic relations in blood and tissues. (6) It maintains the different normal levels of the different substances in the blood. (7) It maintains the ionic balance in the blood and tissues. (8) It eliminates various toxic substances and drugs from the body along with urine. (9) It manufactures certain new substances like ammonia, hippuric acid and inorganic phosphate. (10) It possesses detoxicating function. The benzoic acid conjugates with glycine and forms hippuric acid. (11) Under pathological condition, the juxta glomerular apparatus of the kidney secretes the hormone, Renin, which converts the plasma protein, hypertensinogen into hypertensin. This hypertensin causes constriction of the blood vessels and as a result there will be rise of blood pressure.

Q. 3. Describe the Juxtaglomerular Apparatus. How Renin is formed and discuss its mechanism of action.

The kidney after longitudinal section consists of renal cortex and renal medulla. In between the two zones, there is a special zone present known as *Juxtamedullary Zone*. The nephron of this zone froms an apparatus known as Juxtaglomerular apparatus which secretes *Renin Mc. Manus* in 1940 used the term Juxtaglomerular complex against this apparatus.

Juxtaglomerular Apparatus : *Goormaghtigh* in 1940 gave the term "Juxtaglomerular apparatus" which consists of granular juxtaglomerular cells in the afferent renal arteriole, mascula densa of the distal convoluted tubule and agranular Polkissen or Lacis cell situated in the angle formed by the entrance and exit of the afferent and efferent renal arterioles of each glomerulus. (1) **Juxtaglomerular Cells :** These are granular myoepitheloid cell situated in the affeent arteriole of the juxta-medullary glomerulus. (2) **Macula densa :** During emergency, a portion of the distal convoluted tubule comes in contact with the afferent glomerular vessel of the same nephron. The epithelial cells of the distal convoluted tubule are converted into myoepitheloid cells which become packed together to from macula densa. They produce secretory granular structures that liberates *Renin.* (3) **Polkisen or Lacis Cell :** These are agranular or occasional granular cells, found within the vascular region at the angle formed by the entrance and exit of the afferent and efferent glomerular vessels.

Formation of Renin : Renin is an excretory hormone secreted from the granular myoepitheloid cells present in the efferent renal arteriole and the macula densa of the distal convoluted tubule. It is also formed from the agranular Polkissen or Lacis cell which are situated in the angle formed by the entrance and exit of the afferent and efferent renal arterioles of each juxtamedullary glomerulus. Renin is liberated in the ischaemic condition of the kidney when renal blood supply is deficient to some extent.

Mechanism of the action of Renin : Renin is a proteolytic enzyme produces hypertension in ischaemic condition of the kidney. The increased blood pressure produces increased tubular sodium-load in the mascula densa of the distal convoluted tubule near the juxtaglomerular region and liberates renin which acts on α_2-globulin (angiotensinogen or hypertensinogen)substrate of plasma protein and forms *Angiotensin I* (decapeptide) The plasma enzyme (converting enzyme) interacts with Angiotensin *I* and forms *Angiotensin II* (Octapeptide). It constricts blood vessels and raises systemic blood pressure producing renal hypertension. The adrenaline and nor-adrenaline also help for the liberation of renin. The vasopressin of the posterior pituitary, aldosterone of the adrenal cortex and Angiotensin II have got inhibitory effects on renin liberation which is proved by the Intra-renal Sodium-feed-back theory.

Q. 4. Describe the role of kidney in the maintenance of Acid-Base Balance or pH of Blood.

The kidney maintains the acid-base balance or pH of the blood by the following mechanisms :

I. **Acid or Alkali Mechanism** : The kidney maintains the acid-base balance by directly excreting out the acids or alkalies which accumulate in blood with the urine. During Starvation or in Diabetes mellitus, large amount of acids accumulate in the blood which excrete out with the urine to maintain the normal pH of the blood. Similarly, in high altitudes, large amount of sodium bicarbonate accumulates in the blood or after heavy meal, large amount of alkalies accumulate in the body which excrete out with the urine to maintain the normal pH of blood.

II. **Alkali Reserve of Blood** : The kidney regulates the acid-base balance by preserving the alkali reserve of blood. The bicarbonate is the chief alkali reservoir of blood and available for neutralisation of acid. The diminution of alkali reserve of blood is known as Acidaemia. In acidosis, reaction of blood does not become acid, but the reserve of alkali becomes less. Increase in alkali reserve is known as alkalimia (a) The Acidosis may occur due to : (i) By taking certain drugs such as ammonium chloride. It decomposes into ammonia and hydrochloric acid and ammonia escapes through and hydrochloric acid diminishes the alkali reserves. (ii) During muscular activity, large amount of CO_2 and lactic acid is produced. (iii) In diabetes mellitus certain acids e.g. β-hydroxy butyric acid, Aceto-acetic acid are produced and appear in the blood. (iv) During starvation. (v) Taking of excessive protein product as they contain sulphur and phosphorus and thereby sulphuric acid and phosphoric acids are produced. (b) The Alkalosis may be produced due to : (i) When ammonium bicarbonate is taken as a drug. (ii) The vegetable food stuffs as they contain citrates and tartrate and carbonates and CO_2 enters the blood stream and thereby increases the alkalinity. (iii) In voluntary deep breathing known as hyperpnoea, as in it, acid is liberated in large quantities

III. **Phosphate Mechanism** : In the glomerular filtrate i.e. in the lumen of the kidney tubule, large amount of alkali phosphate is present.

The dissociation of alkali phosphate will give sodium ion and phosphate ion. In the tubular epithlial cell, formation of carbonic acid takes place by the conjugation of carbon dioxide and water with the help of carbonic anhydrase.

The dissociation of carbonic acid will give rise to hydrogen and bicarbonate ion, but tubular epithelial cells secrete hydrogen ion which will go to the lumen of the kidney tubule and will conjugate with sodium ion and phosphate ion to give rise to sodium hydrogen phosphate which will be excreted out with the urine. The tubular epithelial cells secrete sodium ion which will go to the peritublar space and will conjugate with bicarbonate ion.

IV. **Ammonia Mechanism :** The kidney maintains the acid-base balance by ammonia mechanism. The lactic acids accumulate in the blood during muscular exercise. The lactic acid reacts with the buffer sodium proteinate, forms sodium lactate and reduced protein Sodium lactate in the lumen of the kidney tubules dissociates into lactate ion and sodium ion.

The amino-acid alanine in the tubular epithelial cells give rise to ammonia by the deamination process and the enzyme deaminase. The carbon dioxide and water conjugate in the tubular epithelial cells to give rise to carbonic acid with the help of carbonic anhydrase. The carbonic acid dissociates into hydrogen ion and bicarbonate ion. The tubular epithelial cells secretes ammonia and hydrogen ion which will conjuate with lactate to give rise to ammonium lactate which will be excreted out with the urine.

Q. 5. Describe the role of kidney in the regulation of the water balance of the body.

The kidney helps in the reabsorption of water from the renal tubules and also prevents the filtration of the colloids which take part in the maintenance of normal osmotic pressure of the blood and thereby regulates the water balance of the body.

Regulation of Water Balance of the Body : 170 litres of water are filtered through the glomerulus in 24 hours of which 168·5 litres will be reabsorbed back into the blood from the kidney tubules to maintain the normal blood volume and thereby regulate the water balance of the body.

I. **Role of Posterior Pituitary :** The anti-diuretic hormone (A.D.H.) is secreted by the posterior pituitary gland under the influence of hypothalamus through supra-optico-hypophyseal tract. It helps in the reabsorption of 15% to 20% of reabsorbed water from the distant kidney tubule and it is called as "*Facultative Reabsoption.*" 80% to 85% of water will be reabsorbed from the proximal kidney tubules which depends upon the reabsorption of solutes from the kidney tubule and it is known as "*Obligatory Reabsorption.*" The secretion of anti-diuretic hormone and thereby reabsorption of water from the distal part of the kidney tubule depend upon the blood crystalloid osmotic pressure.

When the blood osmotic pressure is high e.g. dehydration due to any cause, there will be more secretion of A.D.H., more reabsorption of water and urinary output is maintained and therefore normal water balance of the body is maintained. When the blood osmotic pressure is low e.g. intake of a large amount of water, there will be less secretion of A.D.H., less reabsorption of water from the kidney tubules and more secretion of water with the urine to maintain the normal water balance of the body. This particular condition is known as "*Water Diuresis*".

II. **Role of Supra-renal Cortex :** The aldosterone hormone of adrenal cortex regulates the water balance of the body by helping in the reabsorption of sodium as sodium chloride and thereby helping in the reabsorption of water from the proximal part of the kidney tubules.

In *Cushing's Disease*, there will be more reabsorption of sodium chloride and with that more reabsorption of water and thereby blood volume is increased. In *Addison's Disease*, large amount of water will be excreted out with the urine due to the excretion of large amount of sodium chloride with the urine and blood volume will be diminished.

III. **Role of Hypothalamus :** When the supra-optico-hypophyseal tract is sectioned, there will be no secretion of A.D.H., no reabsorption of water from distant kidney tubule and large amount of water will be excreted out with the urine to produce a condition known as "*Diabetes Insipidus*".

IV **Role of Adrenal Medulla :** The adrenal medulla liberates adrenaline which after injection reduces urine volume by the constriction of the renal arterioles and thereby the renal circulation is reduced consequently.

V. **Role of Thyroid Gland :** Thyroxine is liberated from the thyroid gland which increases urine volume along with increased elimination of salts by raising the general metabolism and thereby nitrogenous end products are more eliminated causing diuresis. The fluid retention in the extracellular tissue becomes increased by ***Myxoedema***.

VI. **Role of Vasomotor Sysetm :** The vasoconstrictor and vasodilator nerves play an important role in the regulation of water balance by controlling renal circulation and general blood pressure.

Q. 6. Describe the part played by Renal Tubules in the mechanism of Urine Formation.

The nephron is the structural and functional units of kidney. The different parts of the nephron possess different peculiarities in their structure and function. The renal tubule by its different parts help in the formation of urine. A number of theories put forward to establish the mechanism of urine formation but none of them come into final conclusion.

Mechanism of Urine Formation :

(a) According to **Bowman** in 1842, the filtration process provided only the urinary water and the solutes of the urine were added by the secretory activity of the cells of the renal tubules. He established the first plausible theory of urine formation known as filtration-secretion theory.

(b) According to **Ludwig** in 1844, formation of urine is a process of filtration. The effective filtration pressure in the glomerulus is sufficient to filter all the constituents of the blood excepting the colloids. He enunciated an opposing theory known as filtration-reabsorption theory. *Ludwig* could not satisfactorily explain the phenomenon of filtration.

(c) According to **Heidenhain** in 1875, formation of urine is entirely a process of secretion. Water and salts are the secretory products of the glomerular membrane and the organic constituents are the secretory products of the tubular epithelial cells. He supported *Bowman* and by his classical experiments with indigo-carmine, established the tubular secretion theory.

(d) According to **Cushny** in 1917, the formation of urine depends upon the following factors : (1) Filtration through the glomerulus. (2) Selective reabsorption from the kidney tubules. (3) Secretion by the tubular epithelial cells. (4) Manufacture of new substances by the tubular epithelial cells.

Explanation of the Mechanism of Urine Formation :

I. **Filtration Theory :** The effective filtration pressure in the glomerulus is 40 m.m. mercury and is sufficient enough to filter all the constituents of the blood into the Bowman's capsule excepting the colloids.

$$\begin{aligned} \therefore \quad \text{E.F.P.} &= \text{Cp} - \text{Pp} - \text{Pc} \\ &= 70 - 25 - 5 \text{ m.m. Hg.} \\ &= 70 - 30 = 40 \text{ m m. Hg.} \end{aligned}$$

Where, E. F. P. = Effective filtration pressure, Cp = Glomerular Capillary pressure, Pp = Osmotic pressue exerted by the plasma protein and Pc = Intracapsular hydrostatic pressure i.e. pressure in the Bowman's capsule

Evidences : (1) *Richard* introduced micropipette into the Bowman's capsule collected fluid from the capsule, analysed them and found that the concentations of the different constituents of the capsular fluid were same as that of the blood plasma. (2) If the filtration is increased by increasing the total capillary pressure or by reducing the osmotic pressure, there will be increased filtration through the glomerulus and increased formation of urine.

II. **Selective Reabsorption Theory :** Some of the substances after their filtration through the glomerulus are reabsorbed back either fully or partially from the renal tubules to maintain the normal constituents of blood and this substance are known as *threshold substances*. The substances which after their filtration through the glomerulus are not reabsorbed back into the blood, but are excreted out of urine, are known as *non-threshold substances*.

(a) **Reabsorption of Glucose :** Under normal conditions, approximately 100 milligrams of glucose are filtered through the glomerulus per minute. Glucose reabsorbed entirely from the proximal part of the kidney tubule by the process of *phosphorylation*. The maximum amount of glucose present in 100 ml. of blood which can be fully reabsorbed back into the blood from the kidney tubule is called the renal threshold value of glucose and it is 180 milligrams per 100 ml. of blood.

(b) **Reabsorption of Water :** 170 litres of water are filtered through the glomerulus into the Bowman's capsule in 24 hours. 168·5 litres of water are reabsorbed back into the blood from the kidney tubules to maintain the normol blood volume and therefore the daily urinary output becomes 1·5 litres. 80% of water is reabsorded from the proximal tubules without the help of any hormone and this type of reabsorption is known as *Facultative Reabsorption*. 20% of water is reabsorbed from the distal tubules with the help of A.D.H. of the posterior pituitary and this type of reabsorption is known as *Obligatory Reabsorption*.

(c) **Reebsorption of Sodium :** It is reabsorbed both from the proximal and distal parts of the renal tubules. The hormone, aldosterone of supra-renal cortex helps in the reabsorption of sodium from the kidney tubules. If the gland is removed, there will be no reabsorption of sodium and all the sodium will be eliminated out with urine

III. **Secretory Theory :** Some of the constituents of the urine such as creatinine, hippuric acid, benzoic acid, potassium and hydrogen ion are secreted by the tubular epithelial cells.

Evidences : (a) When the dye, Diodrast (Diodone) is injected into the system it can not be detected in the Bowman's capsule, but can be detected in the different parts of the renal tubules, when collected by Richard's micropipette (b) In some fishes there are no glomeruli and urine formation takes place entirely by secretory mechanism. (c) Studies with radio-active potassium present in the urine in the secretory product of the tubules. (d) Para-amino-hippuric acid (PAH) after intravenous administration, 90% of it is through the renal tubules.

IV. **Manufacture of New Substances :**

(a) *Manufacture of Ammonia* **:** The tubular epithelial cells manufacture ammonia from the amino-acids by the process of deamination with the help of an enzyme known as deaminase.

(b) *Manufacture of Hippuric acid* **:** In the tubular epithelial cells, Benzoic acid combines with the glycine to from hippuric acid. Most of the hippuric acid is formed in the liver and a small amount of hippuric acid is manufactured in the kidney.

(c) *Manufacture of Inorganic Phosphate*: The rental tubular epithelial cells manufacture inorganic phosphate from organic hexose phosphate by hydrolysis with the help an enzyme known as phosphatase.

Q. 7. Write what do you know about the Composition of Urine.

The Kidneys may excrete almost any substance which circulates through their blood vessels, many of the intermediate metabolites may be found in minute quantities in the urine. The composition of urine must, therefore, vary according to the activity of the body, the quantity and nature of the food taken and the relative amount of water escaping by other channels. But we can describe an average composition for the urine.

I. Physical Properties :

(a) **Nature :** The urine is a clear yellow fluid which froths when shaken.

(b) **Total quantity :** Average 50 oz. or 1500 ml. per day.

(c) **Colour :** It varies with the concentration of urine. After severe sweating, the urine may be very pale.

(d) **Odour :** The ordinary urine has an aromatic odour, but this varies largely with the character of the food.

(e) **Specific gravity :** The specific gravity of the urine is proportional to its concentration. (i) *In normal condition of health* : It varies between 1010 to 1025 depending on the water intake and solid contents. (ii) *In pathological conditions* : It becomes 1040 or more. (iii) *In chronic nephritis* : The specific gravity become lower and becomes 1010.

(f) **Osmotic pressure :** It is usually much above than that of the blood plasma. The osmotic pressure of urine normally varies between 0·87 and 2·71 degree.

(g) **PH :** It varies fram 4·7 to 7·1 and the average normal hydrogen-ion-concentration becomes 5·3.

(h) **Reaction of the urine :** Urine is acidic in reaction due to the presence of acid sodium phosphate and organic acids like lactic acid, oxalic acid, hippuric acid etc.

(i) **Alkaline tide :** Soon after meals, owing to ingestion of alkaline salts of green vegetables and also for secretion of hydrochloric acid in the stomach during digestion, the urine becomes alkaline in reaction.

II. Chemical Composition : The urine is mainly composed of 95% water and 3% to 5% solids. The inorganic and the organic constituents of solids in 1000 ml. of urine of a healthy adult on an ordinary mixed diet are as follows :

A. Inorganic Constituents :

Ingredients :		Grams per 1000 ml.
(1) Chloride expressed as NaCl	...	9·0
(2) Phosphorus expressed as P_2O_5	...	2·0
(3) Total Sulphur expressed as SO_3	...	1·5
(i) Inorganic Sulphates.		
(ii) Ethereal Sulphates.		
(iii) Neutral Sulphur.		
(4) Sodium expressed as Na_2O	...	4·0
(5) Potassium exprssed as K_2O	...	2·4
(6) Calcium expressed as CaO	...	0·2
(7) Magnesium expressed aa MgO	...	0·2
(8) Iron	...	0·003

B. Organic Constituents :

(a) Nitrogonous (N.P.N.)

(1) Urea 5·0 gms./1000 ml.
(2) Ammonia 0·6 ,,
(3) Uric acid 0·6 ,,
(4) Creatinine 1·5 ,,
(5) Hippuric acid 0·1 to 0·5
(6) Pigments
(7) Amino-acids
(8) Aromatic Substances
(9) Indican
} 1·0 to 1·5 gms/1000 ml.

(b) Non-Nitrogenous.

(1) Oxalic acid 20 to 30 mgms/1000 ml.
(2) Lactic acid 75 to 200 ,,
(3) Aceto-acetic acid
(4) β-hydroxy butyric acid
(5) Glycuronic acid
(6) Other organic acids
} **Traces**

(c) Other Organic Substances : They are present in urine in small amounts or in traces The organic substances are :

(1) **Pigments :** Urochrome and Urobilin
(2) **Sugar :** 2 to 3 mg%
(3) **Fatty acids :** Aceto-acetic acid and β-hydroxy-butyric acids.
(4) Carbonates, bicarbonates and free carbonic acids.
(5) Mucin, mucin like substances and diastase.

C. Hormones in the Urine :

(a) Derivatives of Oestrone and Oestrol.

(b) Derivatives of testosterone, androsterone, trans-dehydroandrosterone and dehydro-epiandrosterone.

(c) Derivatives of progesterone e.g. pregnandiol.

(d) Neutral 17-ketosteroids and adrenocorticoid hormones.

(e) Antiduretic hormone of the posterior pituitary.

(f) Diabetogenic hormone, Somatotrophic hormones, and Thyrotrophic hormone of the Anterior Pituitary.

Q. 8 Describe the Pathogical (Abnormal) Constituents of urine and their tests.

Kidneys may excrete almost any substance which circulate through their blood vessels, many of the intermediate metabolites may be found in minute quantities in the urine. Under pathological conditions, these metabolities may apper in the urine in larger amounts and serve them as an index to some interference with metabolism. A large number of substances occur in minute traces in the urine. Most of the so-called pathological constituents may be detected in traces in normal urine. It is only when they occur in easily detectable amounts and their presence becomes of clinical significance.

Pathological Constituents of Urine and their Tests : The pathological constituents of urine are albumin, blood, chyle, bile salts, bile pigments, indican, methaemoglobin, haemoglobin, glucose, pentoses, acetone and pus. These constituents have got some source of origin in the urine and they are tested by different bio-chemical tests.

(a) **Albumin :** It is one of the constituents of plasma protein.

Source of Albumin in the urine : The source of origin of albumin in the urine are the following : (1) Due to congestion in the kidneys, as in uncompensated cardiac diseases or the dilatation due to myocardial diseases. (2) In fevers and in anaemia possibly due to degenerative changes, in the kidneys. (3) In acute infections such as Diphtheria, Typhoid and Streptococcal septicaemia etc. (4) In Toxaemia of pregnancy and taking certain drugs like Arsenic, Mercury and other Heavy metals like lead, bismuth etc.

Tests for Albumin : The pathological albumin is tested by the following ways : (1) The urine is slowly run on to a little concentrated cold nitric acid in a test tube. A white ring of the fluids appears at the junction which is due to precipitation of coagulable protein. (Heller's Ring Test). (2) The solutions of saturated picric acid would produce a precipitate which disappears on heating if due to nucleoprotein mucins but it deepens if due to albumin or globulin. (Esbach's Test).

(b) **Blood :** It is a liquid connective tissue generally present in the cardio-vascular structure but may be present in the urine in pathological conditions.

Source of Blood in the urine : The source of origin of blood in the urine are the following : (1) In acute nephritis and in stone formation in the kidney, ureter, urinary bladder or urethra. (2) In ulcers or new growths anywhere in the urinary tract. (3) In parasitic infections like filaria or by B. Coli infection.

Tests for Blood : A few drops of Benzidine dissolved in glacial acetic acid is mixed with urine and hydrogen peroxide is added to it and a blue colour appears. (Benzidine Test).

(c) **Chyle :** *Source of Chyle in the urine* **:** The chyle is present in the urine in case of infection of filaria and chyluria etc.

Tests for Chyle **:** (1) The chylous urine if examined under microscope, may show the microfilariae. (2) On shaking chylous urine with ether, the fat is dissolved by ether and urine becomes clear.

(d) **Bile Salt :** It is one of the important constituents of bile and it has got two varieties namely sodium taurocholate and sodium glycocholate.

Source of Bile Salt in the urine **:** Bile salt may appear in the urine in all conditions of Jaundice or Cholaemia.

Tests for Bile Salt **:** Flowers of sulphur are sprinkled on the icteric urine, it will sink because bile salts reduce the surface tension, but they float on the normal urine. (Hay's Surface Tension Test).

(e) **Bile Pigments** : The bile pigments are the main constituents of bile which are bilirubin and biliverdin.

Source of Bile Pigment in the urine : The presence of bile pigments in the urine is duo to : (1) In the conditions of haemolysis of the blood and formation of more bilirubin in the reticulo-endothelial system. (2) In Jaundice and malignant malaria.

Tests for Bile Pigments : Pour strong nitric acid along the side of the test tube containing some icteric urine, there will be a play of colours at the junction such as red, green and blue due to gradual oxidation of bilirubin to bilicyanin and finally to yellow. If a filter paper soaked in the urine and partially dried, is touched with a drop of nitric acid, the play of colour becomes more vivid (Gmelin's Test).

(f) **Indican** : *Source of Indican in the urine* **:** Indoxyl is formed from the amino-acid Tryptophane by the bacterial digestion in the large intestine.

Tests for Indican **:** A solution of lead acetate is added to the urine and fiter. To the filtrate add strong HCl containing a trace of ferric chloride that develops indigo-blue colour a little choroform and shake, the chloroform takes the blue colour beautifully and settles at the bottom. (Obermayer's Test).

(g) **Methaemoglobin or Sulphaemoglobin :** These are compounds of haemoglobin The methaemoglobin arises by the spontaneous oxidation of the ferrous iron of haemoglobin to the ferric state. The sulphaemoglobin arises from the combination of sulfurated hydrogen with haemoglobin.

Source of Methaemoglobin in the urine **:** (1) It has been formed haemoglobin in any acid urine containing blood, after sometime. (2) It is present in urine due to haemoglobin of the neighbouing structures of the kidney.

Tests for Methaemoglobin : (1) The appearance of the patient without the evidence of any marked dyspnoea. (2) Spectroscopic examination.

(h) **Haemoglobin** : Haemoglobin is a chromoprotein or coloured protein. It is the main constituents of red blood cells.

Source of Heamoglobin in the urine : The haemoglobin may be present in the urine due to certain toxic agents as is found in a condition known as black-water-fever.

Tests for Haemoglobin : (1) The colour of the urine usually becomes red and there are corpuscles found under the microscope. (2) Spectroscopic examination.

(i) **Glucose** : It is a final digestive end products of carbohydrate food stuffs.

Source of Glucose in the urine : (1) Glucose is found in the urine in the condition known as Diabetes mellitus. (2) Other substances which might give similar tests as for glucose, are excess of uric acid, creatinine, glycuronates etc. which should be thought of and eliminated.

Tests for Glucose : Take equal part of Fehling's solution I and Fehling's solution II in a test tube and boil and add equal quantity of urine and again boil. If there is much sugar, there is an immediate brown or red precipitate of cuprous oxide. (Fehling's Test).

(j) **Pentoses** : *Source of Pentose in the urine* : (1) Pentose may occur in the condition known as pentosuria. (2) After ingestion of large amount of food.

Tests for Pentose : 5 ml. of Bial reagent (0·5 gm. Orcinol, 170 gms. fuming HCl and 10 drops or 10% $FeCl_3$ solution are boiled in a test tube and 2 to 3 ml. urine are added. The heating is stopped and the solution turns green if pentoses are present. (Bial Test).

(k) **Acetone** : It is a ketone formed after fatty acid oxidation.

Source of Acetone in the urine : Acetone is found in the urine in acidosis of diabetes, during starvation and after ether or chloroform narcosis.

Tests for Acetone : To some urine add ammonium chloride or sulphate crystals almost to saturation. Add few drops of freshly prepared solution of sodium nitroprusside. Now pour slowly strong NH_4OH solution down the side of the test tube, a purple colour at the junction indicates the presence of acetone (Rothera Test).

(l) **Pus** : *Source of Pus in the urine* : Pus appears in urine as a consequence of suppuration in any part of the urinary tract or its neighbourhood. The sediment of pus is almost always mixed with phosphates.

Tests for Pus : (1) On the addition of caustic potash to the deposit of pus cells a ropy gelatinous mass will be formed whereas mucous treated in the same way undergoes solution. (Chemical Test). (2) The reaction is possible in Guaiac solution but the blue colour disappears on boiling the mixture, whereas that producee by blood, does not. (Guaiac Reaction).

Q. 9. Describe the Nitrogenous Constituents (N.P.N.) of Urine and their origin and significance.

The urine is a clear yellow fluid which contains 95% water and 5% organic solids. The organic constituents contain nitrogenous and non-nitrogenous substances. The nitrogenous constituents of urine are Urea, Uric acid, Creatinine, Ammonia, Hippuric acid, Xanthine and Hypoxanthine.

(a) **UREA :** It is a carbamide and metabolised end product of protein and nucleo-protein.

Origin : Urea is formed in the liver by the following ways :

(1) Urea is fromed from the amino-acids by the process of deamination with the help of an enzyme known as deaminase. Ammonia derived from deaminated amino-acids will combine with CO_2 to form ammonium carbonate. This ammonium carbonate looses one molecule of water and is converted into ammonium carbamate. This ammonium carbamate looses one molecule of water and is converted into urea. (Ammonium-Carbonate method Theory).

(2) Urea is also derived from Kreb's Ornithine Cycle. Ornithine combines with Ammonia and CO_2 and is converted into Citrulline. This Citrulline will combine with Ammonia and will be converted into Arginine. This Arginine with the help of an enzyme arginase will be converted into Orithine and Urea.

(3) Urea is formed in the liver, though to a very small extent, from the breaking down of tissue proteins.

Significance : The excretion of urea signifies both exogenous and endogenous protein metabolism. During starvation, it is an index of endogenous protein metabolism. More will be the protein intake, more will be the excretion of urea.

(b) **URIC ACID :** It is the final end product of purine metabolism in man and is excreted in urine of about 0·5 gm. to 1 gm. per 24 hours but the amount is subject to wide variation, particularly under certain dietary and pathological conditions.

Origin : Uric acid is formed in the liver in the following ways :

(1) Nucleo-protein and other purine-containing substances of the food after digestion in the alimentary tract, produce phosphoric acid, pentose carbohydrate and purine and pyrimidine bases. The purine base contains adenine and guanine which are deaminised in the liver and form hypoxanthine and xanthine respectively. Hypoxanthine is oxidised by hypoxanthine oxidase to xanthine which again is oxidase by

xanthine oxidase to uric acid. (2) Uric acid is formed from the nucleo-proteins of the tissues. (3) Uric acid may be fromed from the amino-acids like arginine and histidine.

Significance : The excretion of uric acid signifies both exogenous and endogenous nucleo-protein metabolism.

(c) **CREATININE :** It is the anhydride of creatine. The amount of creatinine excreted out with the urine is 1·5 gm. in 24 hours.

Origin : Creatinine is formed in the muscles during muscular metabolism. The phosphagen or creatine phosphate of muscle will break down into creatine and phosphoric acid during muscular activity. A small fraction of creatine becomes dehydrated and it is converted into creatinine.

Significance : Creatinine excretion signifies muscular metabolism. The quantity of creatinine in urine is greater in muscular persons and appears to bear a relation to the muscular development of the individual rather to its muscular activity.

(d) **AMMONIA :** It helps in the formation of urea after combining with carbon dioxide and water. It is one of the nitrogenous waste products of the body. The amount of ammonia excreted in 24 hours is 0·9 gm.

Origin : Ammonia is derived from the amino-acids by the process of deamination with the help of an enzyme "deaminase" with the tubular epithelial cells.

Significance : Ammonia depends on the reaction of the blood where it is utilised for neutralising the acid radicles, thus sparing the fixed bases of the plasma.

(e) **HIPPURIC ACID :** It is a conjugated product of benzoic acid and glycine.

Origin : The tubular epithelial cells manufacture hippuric acid by the conjugation of benzoic acid glycine. Most of the hippuric acid is formed in the liver and a small amount of hippuric acid is formed in the kidney which is proved by "Kidney Perfusion Experiment".

Significance : The hippuric acid excretion signifies the utilisation of benzoic acid and glycine in the renal tubule.

(f) **HYPOXANTHINE AND XANTHINE :** These are the breakdown product of purine bases of nucleo-protein ; like adenine and guanine.

Origin : The hypoxanthine and xanthine are intermediary metabolic products of adenine and guanine. These are formed in the liver by deamination of purine bases. When adenine and guanine are not completely converted into uric acid, the incompletely oxidative product such as hypoxanthine and xanthine will be excreted out along with urine.

Significance : The excretion of hypoxanthine and xanthine signify equally both exogenous and endogenous metabolism of purine nucleoprotein.

(g) **AMINO-ACID :** The sulphur containing amino-acids like cystine excretes out with the urine as Neutral Sulphur compounds.

Q. 10. Describe the Physiology of Micturition.

Micturition is one of the physiological process of evacuation of urinary bladder content which is mostly controlled by involuntary and voluntary processes. The involuntary process is done by reflex action and the reflex actions are mostly autonomic and partly somatic in nature. The process of evacuation takes place at irregular intervals normally and the number of evacuation takes place throughout the day at four to six times and at each evacuation, the amount of fluid evacuates is 300 to 400 ml.

Filling of the Urinary Bladder : The ureters exhibit rhythmical petistaltic contractions which travel at a speed from 20 to 25 m.m. per second (Rabbit) and at frequency from 1 to 5 per minute,

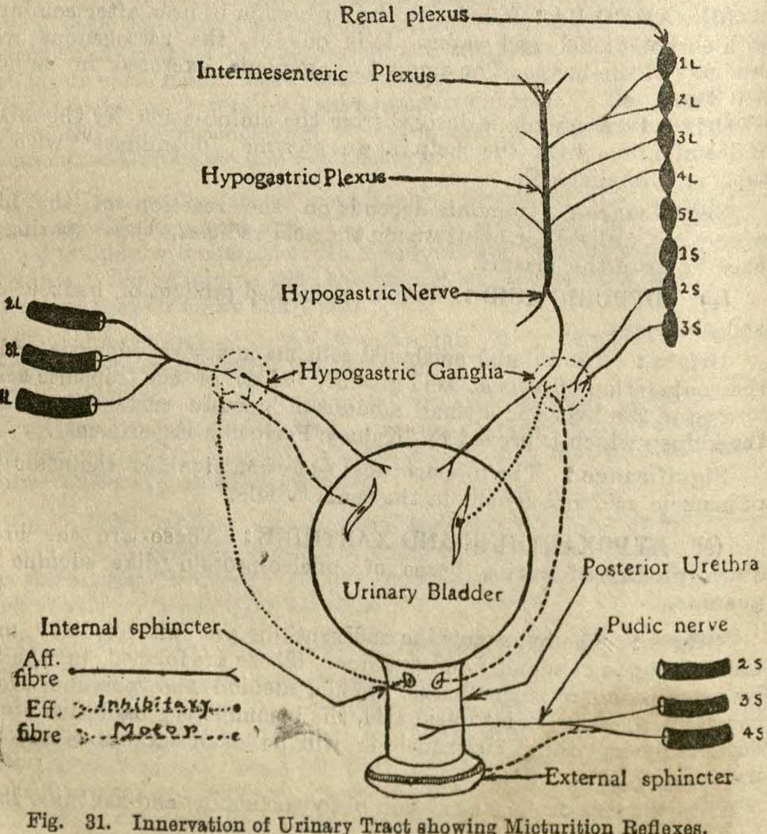


Fig. 31. Innervation of Urinary Tract showing Micturition Reflexes.

according to the volume of urine formed by the kidney. The detrusor muscles of the bladder exhibit two types of activity :

(a) *A Substained Contraction or Tonus* : The bladder is capable of adjust its tone and so of adapting its capacity to changes in volume of its contents with relatively little alternation in internal pressure.

(b) *The Intermittent Rhythmic Contaction* : It arises during the filling of bladder and its tension increases with increase of more fluid and stronger contraction for evacuation occurs.

Innervation of Urinary Tract : The process of micturition is done by centres, nerves and reflexes.

(a) **Centres :** The centres governing micturition are the cortical

No. of Reflexes	Centres	Nerves		Results.
		Afferent	Efferent	
1.	Hind-brain	Pelvic	Pelvic	Contraction of the detrusor muscle which is accompanied by reciprocal relaxation of the internal sphincter causing distension of the bladder.
2.	Hind-brain	Pudic	Pudic	Contaction of the detrusor muscle caused by running fluid through the urethra.
3.	Lumbo-sacral part of the spinal cord.	Hypo-gastric	Hypo-gastric	Contraction of the deterusor muscle when the proximal portion of the urethra is distented.
4.	Lumbo-sacral part of the spinal cord.	Pudic	Pudic	Relaxation of the external sphincter when the fluid passes through the urethra.
5.	Lumbo-sacral part of the spinal cord.	Pelvic	Pudic	Relaxation of the external sphincter when the bladder is distended.
6.	Lumbo-sacral part of the spinal cord.	Pelvic	Pelvic	Relaxatiou of the plain muscles of the proximal one-third of the urethra caused by distension of the bladder.

centre situated in the cerebral cortex, hypothalamic centre situated in the hypothalamus, mid-brain centre situated in the mid-brain, hind-brain centre situated in the hind-brain and spinal cord centre which is situated in the lumbar and sacral segments of the spinal cord. The cerebral cortex is the highest centre which has got inhibitory influence over the lower micturition centres. Hypothalamus in the centre for autonomic nervous system and can modify the act of micturition.

(b) **Nerves :** The nerves governing the micturition are the afferent and efferent nerves. The afferent nerves are the Sympathetic or hypogastric or nerve filling or pre-sacral nerves ; Parasympathetic or pelvic or nerve of emptying and somatic or pudic or pudendal nerves. The efferent nerves are the sympathetic and parasympathetic nerves.

(c) **Reflexes :** *Barrington* in 1931, describes six integrated reflexes as constituting the act of micturition in cat which is shown as a tabular form :

Q. 11. Describe the course of Circulation through the Kidney and discuss the peculiarities of Renal Circulation.

The circulation of blood is a phenomenon by which heart in one hand receives impure blood from the body and on the other hand pure blood comes out from the heart and supply to the different parts of the body. The circulation of blood through the kidney is known as renal circulation. The renal circulation is primarily a glomerular circulation and all the branches that arise from archiform and inter-lobular arteries terminate in glomeruli.

Factors Influencing Renal Circulation : The renal blood flow depends upon the following factors :

(a) **Glomerular Pressure :** (1) General level of blood pressure —It is maintained by the difference of pressure of afferent and efferent vessels. (2) Constriction of afferent vessel—It interposes additional frictional resistance resulting fall of glomerular pressure. (3) Constriction of the efferent vessel—It damps up the blood proximally so that glomerular pressure rises. (4) Filtration friction—Its rise in man is interpreted as representing raised glomerular pressure.

(b) **Physiological Factors :** (1) Cardiac Output—The renal blood flow constitutes about one-quarter of the total cardiac output at rest. (2) Level of the arterial blood pressure—It is higher than the pressure in capillaries and may sometimes equal to the diastolic blood pressure. (3) Calibre of the renal arterioles and capillaries.

Renal Circulation :

I. **General Circulation :** This type of circulation is done by arterial flow by renal artery and venous drainage by renal vein.

(a) **Arterial Supply :** The renal artery divides into 6 to 8 branches before entering through hilum. Each branch on entering the sinus divides into 6 to 8 *labar arteries*. Each labar artery divides into *interlobar branch* which pass through the renal columns lying between two pyramids and divides dichotomously into two *archiform arteries.* The inter-lobar and archiform arteries are end arteries.

From the cortex side of archiform artery, *inter-lobar arteries* go through cortex and end by supplying the capsule. On its way, it sends afferent artery to form glomerulus within Bowman's capsule. From the afferent vessel, a artery supplies the renal tubular plexus known as *Ludwing's artery.* From the glomerulus away from juxta-medullary cortex, efferent artery of lesser calibre start and go to form inter-lobular plexus. From glomerulus at juxta-medullary cortex, efferent artery starts. It is of same calibre than afferent artery. It pierces the base of the pyramid and go to the apex. The glomerulus at juxta-medullary zone is surrounded by *Trueta Cell* which helps in shunting machanism. From the archiform artery, a artery supply the pyramid known as *True arteria recti* and a artery starts from the afferent vessel of juxta-medullary glomerulus and supply the pyramid known as *False arteria recti.*

(b) **Venous Drainage :** From the interlobular plexus the veins start and end in *interlobular veins* which start as venous stellate from undersurface of the capsule. These interlobular veins end in *archiform veins.* In case of juxtamedullary glomerulus from the afferent arteries, *vena recti* starts and end in archiform vein. These veins unite to form *inter-lobar vein* and again these veins unite to form *lobar veins* within the sinus. These lobar veins unite to form 6 to 8 tributaries. These come out of the hilum and unite to form *renal vein.*

II. **Greater Circulation :** It takes place away from juxtamedullary cortex. Here efferent artery is of lesser calibre than afferent artery, so glomerular pressure becomes high and thereby help in filtration process of the glomerular content.

III. **Lesser Circulation :** It takes place at glomerulus in juxta-medullary zone. Here afferent and efferent arteries are of same calibre So glomerular pressure is not high. It acts in filtration process when there is excessive haemorrhage some where else. It also produces renin which increases renal blood pressure.

IV. **Abnormal Circulation :** (1) The additional branch of renal artery when present may pass in front of renal vein or behind the ureter and serves as a renal circulation. (2) The superior and inferior renal artery which is the branch of abdominal aorta, occassionally serve as renal circulation.

V. **Brodel's line :** The renal artery divides into two sets supplying anterior major and posterior minor part of the kidney. In between the two sets there is a least vascular arch called *Brodel's plane.* This plane is represented by a whitish line, *Brodel's line,* parallel and a little posterior to the lateral border of the kidney.

Peculiarities of Renal Circulation : The peculiarities of renal circulation may be summarised as follows :

(1) *Renal Circulation is a portal system* : The blood has to pass through double capillary network. It at first passes through the glomerular capillaries and then through the peritubular capillaries. So that, almost all blood that reaches the tubule has to port on the glomerular tuft.

(2) *Osmotic pressure* : Renal blood pressure is very high because afferent glomerular vessel is wider and shorter than the efferent vessel. The renal artery is short and wide that arises directly from the aorta and divides into a small number of wide branches.

(3) *Rate of blood supply* : The rate of blood supply to the kidney is comparatively high and 1300 ml. of blood pass through the two kidneys per minute. The total quantity of blood requires 4 to 5 minutes times for circulation through the kidney in the human being.

(4) *Double type of circulation* : There are two types of circulation in the kidney namely greater and lesser circulation. The greater circulation carries 75% of blood whereas lesser circulation carries only 15% of blood.

Q. 12. Describe Kidney Efficiency Test or Kidney Function Test.

The kidney is one of the valuable organ in the body that serves the clearence of different types of nitrogenous wastes from the body. Each kidney is made up of a million of nephorn and each nephron is made up of Malpighian corpuscle and renal tubule. This nephron serves many purposes like formation of different elements and the blood that circulates within the kidney which has got greater importance. To know the kidney in a well organised or well functioned way, we must do different tests for its normal activity.

I. Tests involving an Examination of Blood :

(a) **Urea Determination Test :** By estimating the amount of urea in the blood, the kidney function can be determined.

Low, mean and maximum values of urea in the blood i.e. 10, 30, 48 mg/100 ml. of blood.

In renal insufficiency, it may be anywhere according to the degree of impairment from 60 to 500 mg/100 ml. of blood

(b) **Creatinine Determination Test :** The creatinine content of blood is also sometimes employed as an index of renal function. The normal creatinine content is 1 mg. per 100 ml. of blood.

In severe degree of renal insufficiency, the creatinine may rise as high as 6 mg. per 100 ml. of blood.

II. Tests involving an Examination of Urine :

(a) **Urea Concentration Test of Mclean :** 15 gms. of urea is dissolved in 100 ml. of water. This amount of urea is taken after the complete evacuation of urinary bladder.

The bladder is again emptied 1 hour or 2 hours after the intake of urea solution. The first sample ef urine is discarded as urea acts as a diuretic and urea may be diluted.

The degree of insufficiency of kidney is detected from the percentage of the urea in the second sample of urine.

A concentration of 2% or more indicates normal renal functions.

(b) **Phenol Sulphonaphthalein Test :** The dye is injected intravenously. In normal healthy kindey 65% or more will be excreted within 2 hours. Its elimination is delayed when renal insufficiency exists.

(c) **Water Excretion Test :** In one pint or 500 ml. of water is taken, the whole quantity will be excreted out with the urine within 2 to 3 hours (maximum 4 hours). In damaged kidney, the excretion of water is very much delayed.

(d) **Specific Gravity Test :** The specific gravity of urine is detected after fluids has been witheld for 10 hours or more. The specific gravity will be 1025 to 1032. If the specific gravity becomes less than 1020, it indicates defective reabsorption power of the kidney tubules.

III. **Tests involving an Examination of both Blood and Urine :** Plasma clearance may be defined as the volume of plasma cleared by a given substance per minute by the kidney. Suppose, Ux is the concentration of x per ml. of urine.

V = Rate of urine formation in ml. per minute.

Px = Concentration of x per ml. of plasma.

$$\frac{Ux \times V}{Px} = \text{Volume of plasma required to supply to quantity of}$$

'x' excreted out per minutes.

A substance which is to be used for measuring glomerular filtration rate must satisfy the following requirements : (1) Must diffuse freely through the glomerular membrane. (2) Must not be reabsorbed back into the blood from the kidney tubules. (3) Must be physiologically inert. (4) Must be substance which can be determined accurately in plasma and urine.

A. Urea Clearance Test (Moeller, Mcintosh and Van Slyke) :

Procedure : Two one-hourly samples of urine are collected. At the end of first hour, blood is collected and its urea content (mgm %) is estimated. The samples of urine are measured and their urea concentrations (mgm. %) are estimated separately. The minute output of urine is calculated from these data.

Calculation : (a) *Maximum Clearance* : If the minute output be 2 ml. or more, the result is called *Maximum Clearance*

(Cm). The formula for it as follows : Cm (Maximum Clearance) $=\frac{U\times V}{P}\times 100$. where, P = Amount of urea in the plasma in mgm. per ml., U = Amount of urea in the urine in mgm. per ml. and V = Rate of urine flow in ml per minute. We know that P = 13·2 mgm. per 100 ml. of blood, U = 330 mgm. per 100 ml. of blood and V = 3 ml. per minute. $\therefore\ Cm=\frac{U\times V}{P}=\frac{330\times 3}{13{\cdot}2}$ ml. = 75 ml. (of plasma). For Cm. 75 ml. is taken as the 100% efficiency.

∴ Cm = 100/75 i e. Cm. × 1·33% will give the percentage efficiency for maximum clearance. For instance, if Cm of a subject is found to be 50 ml. the renal efficiency will be 50 × 1·33 i.e., 66·5%,

(b) *Standard Clearance* : If the urine volume is 0·5 to 2 ml. per minute, then the *Standard Clearance* (Cs) becomes $Cs=\frac{U\times\sqrt{V}}{P}=54$ ml. (of plasma). To express as percentage of normal, Cs is to be multiplied by 100/54 i.e., 1·85. As for example, if the Cs of a subject is found to be 50, the renal efficiency will be 50 × 1·85 i.e., 92·5%.

B. **Inulin Clearance Test** : The inulin is a polysaccharide which is not metabolised in the system, not reabsorbed by the kidney tubules, not secreted by tubular epithelial cells, absolutely non-toxic and can be easily detected in the plasma and urine.

This is a more specific test of glomerular filtration than the urea clearance test as inulin is completely filtrable through the glomerulus.

Procedure : 25 gm. of inulin is injected by intervenous route and clearance is measured by determination of inulin in blood and urine. The process is similar to that employed for urea clearance test.

Interpretation : The normal average inulin clearance is 120 ml. of plasma per minute. The normal range varies from from 100 to 150 ml. per minute.

C. **Creatinine Clearance Test :** The principles and procedures are same as above. The creatinine is filtered by the glomeruli and as well as actively excreted by the tubules. The clearance value becomes 170 ml.

D. **Diodrast Clearance Test** : The dye, Diodrast is removed by the kidney through glomerular filtration and tubular excretion. It serves as a basis for clearance determination. The material used is the same as intravenous pyelography. In adults, the normal diodrast clearance is 700 ml. of blood per minute, but the normal range is 520 to 1560 ml. per minute.

IV. **Pyelography Test** : The kidney shadow is taken by X-ray after the injection of radio-opaque substance If kidney shadow cannot be detected in X-ray film, it is concluded that kidney is not functionally in a proper way.

Q. 13. What is Glycosuria ? Describe its different types.

The glycosuria is the presence of glucose in the urine in sufficient quantities (more than 180 mg%) as to reduce Fehling's solution or Benedict's reagent. The occurrence of glycosuria depends upon the sugar content of the blood and renal sugar threshold value.

Different Types ef Glycosuria : There are different types of glycosuria which are discussed as follows :

I. **Renal Glycosuria :** It occurs when the re-absorptive power of glucose by the tubular epithelial cells is diminished and glucose may come out with the urine. The maximum re-absorption of glucose by the tubular epithelial cells is 300 mg. per minute. It may vary from individual and where if it is less than normal, glycosuria may develop.

II. **Phloridzin Glycosuria :** Phloridzin reduces the ability of the renal tubule cells to re-absorb glucose from the glomerular filtrate. It destroys the enzyme phosphorylase which helps the phosphrylation process. The poshorylase enzyme helps the formation of hexose phosphate for its re-absorption through the renal tubules. If there is no hexose phosphate, glucose cannot be re-absorbed from the tubules and all glucose will be eliminated with the urine. This type of glycosuria is not at all associated with the hyperglycaemia.

III. **Nervous Glycosuria :** The stimulation of the sympathetic nervous system supplying the liver or stimulation of the sympathetic pre-ganglionic fibre supplying the supra-renal medulla will cause conversion of glycogen into glucose. This conversion phenomenon produces hyperglycaemia which will lead to glycosuria.

IV. **Puncture Glycosuria :** The puncture of the floor of the fourth ventricle in rabbit is followed by hyperglycaemia and glycosuria, probably due to stimulation of splanchnic nerves. This puncture glycosuria may last for 24 hours or more. It is accompanied by hyperglycaemia and the blood sugar level becomes 300 to 400 mg. per 100 ml.

V. **Hormonal Glycosuria :** This type of glycosuria is caused due to the effect of different types of hormones which are as follows :

(a) *Insulin* : In Diabetes mellitus, glucose will come out with the urine when secretion of insulin becomes deficient or is absent due to the degeneration of the beta cells of the Islets of Langerhans. Due to less insulin effect, glucose canot be converted into glycogen and thereby blood glucose level becomes high, renal thershold value exceeds and the excess of glucose will come out with the urine.

(b) *Glucagon* : It is secreted by the α-cells of the Islets of Langerhans. It activates the inactive phosophorylase and stimulates glycogenolysis producing hyperglycaemia and glucosuria.

(c) *Diabetogenic hormone* : When diabetogenic hormone of anterior pituitary is secreted in increased amount, hyperglycaemia occurs which will lead to glycosuria.

(d) *Thyroxine* : In hyperthyroidism, thyroxine secretion is increased. It will cause glycogenolysis and as a result, there will be hyperglycaemia and glycosuria.

(e) *Gluco-corticoids* : The gluco-corticoids of adrenal cortex when injected into the system, there will be hyperglycaemia and glycosuria.

(f) *Adrenaline* : The adrenaline of adrenal medulla when injected into the system, there will be glycogenolysis, blood sugar level will rise, exceed the renal threshold value and glucose will be eliminated with the urine.

VI. **Alimentary Glycosuria** : After intake of a large amount of sugar after a prolonged starvation, glucose may be absorbed into the blood at a greater rate than that at which initially, the liver and muscles can convert sugar into glycogen and no sugar will be found in the urine when more than 500 gm. of glucose is taken, there will be vomiting, glucose will come out and as a result there cannot be any hyperglycaemia and glycosuria.

Q. 14. Describe the Estimation of Urea in urine quantitatively.

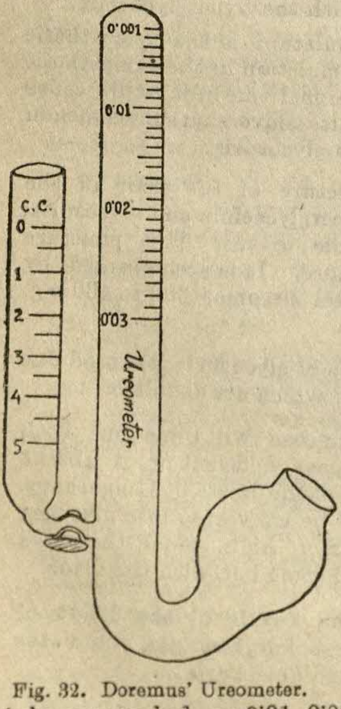


Fig. 32. Doremus' Ureometer.

The estimation of urea in urine is done with the help of an instrument known as Doremus' Ureometer.

Principle : Urea of the urine is decomposed by the hypobromite solution with the evolution of nitrogen and carbon dioxide. The carbonic acid is absorbed by the caustic soda in the test solution and the nitrogen collects at the top of main tube. When all effervescence has ceased in about 15 minutes read off the number of marks upto the upper level of the fluid.

Instrument : The Doremus' ureometer is made up of a V-shaped tube. It consists of a graduated bulb tube, closed at the top and open at the bulbous extremity. There is a side tube, open at the top and provided with a glass stopper at the bottom. The side tube is graduated in ml. and is meant for the urine to be examined. The larger divisions at the upper portion of the bulb-tube are marked as 0·01, 0·02 and 0·03. Each larger division is again graduated in tenths and represents so many grams of urea per ml. of the urine utilised in the test. Each smaller division represents 0·001 gram of urea.

Reagents Required : The sodium hypobromite solution consists of 23 ml. of 30% caustic soda solution to which 2 ml. of soda solution to which 2 ml. of Bromine has been added. The solution is prepared immediately before use.

Procedure : The ureometer if washed with distilled water. The freshly prepared hypobromite solution is poured into the bulb and by tilting the instrument the solution is run into the straight limb of the tube. Observe that no air-bubble is left at the top of the bulb-tube. Pour urine into the side tube upto the mark zero by keeping the stop-cork closed. Now turn the stop-cork and allow one ml. of urine to run slowly into the bulb tube, otherwise the hypobromite solution will be forced out of the tube by too rapid evolution of gas.

Reactions : 3 NaOBr [Alkaline hypobromite]+CO(NH$_2$)$_2$ [Urea] $=3NaBr+2H_2O+N_2+CO_2$

Reading : The number of marks indicates so many grams of urea in 1 ml. of the urine tested. Hence the percentage is found by multiplying the number by 100.

Calculation : If the fluid stands at 0·01 mark, the reading will be 0·01 gram of urea in 1ml. of urine. Therefore in 100 ml. it is 0·01× 100 or 1 gram, i. e. 1% of urea present in the urine tesed.

Significance : The normal blood urea becomes 0·02 to 0·035%. The percentage of urea in the urine depend on the amount of protein intake.

Q. 15. How will you estimate Albumin in urine quantitatively ?

The estimation of albumin in urine is done with the help of an instrument known as Esbach's Albuminometer.

Instrument : The Esbach's albuminometer consists of an elongated glass tube graduated and marked. The markings Ur. and Re. indicate urine and reagent respectively. The numbers like 0·5, 1, 2. 3, 4, etc., indicate grammes of albumin per liter of urine.

Solution Required : (1) *Esbach's reagent* : It consists of 10 grams of picric acid, 20 grams of citric acid in 1000 ml. of distilled water. (2) *Urine* : It must be acidic in reaction. If alkaline, make it acid by acetic acid.

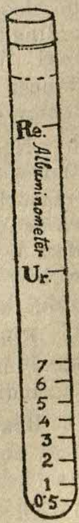


Fig. 33. Esbach's Albuminometer.

Procedure : If the urine is alkaline, render it acid by acetic acid, filter it. Dilute the urine make up the specific gravity 1008. The urine is poured into the instrument upto the mark Ur. and the reagent is added upto the mark Re. The tube is closed and the contents are mixed up by gently inverting it several times. The tube is then set aside in a vertical position. The graduations corresponding to the upper level of the precipitate is read off after 24 hours. The graduation represents dry albumin in grams per litre of urine.

Readings : The figure on the tube represents the amount of albumin in grams per litre of urine. The percentage is found out by dividing the figure by ten. If the urine is rich in albumin, it is diluted with water and its albumin is estimated as above. The result is then multiplies by the degree of dilution.

Significance : The albumin content of plasma becomes 4 5%. It exerts an osmotic pressure of about 25 m.m. Hg, by virtue of which it tends to retain fluid in the capillaries and helps to maintain the blood volume, regulates interchange of fluid between the blood and the tissues.

Q. 16. Write Short Notes On : Threshold Substances, No-Threshold Substances, Ethereal Sulphate, Reaction of Urine and Nitrogenous Equilibrium.

(a) **Threshold Substances :** Some of the substances after their filtration through the glomerulus are reabsorbed back either fully or partially from the renal tubules to maintain their appropriate level in the blood and these substances are known as *Threshold Substances.* According to the rate of reabsorption, the threshold substances are grouped into *High-threshold*, *Mid-threshold* and *Low-threshold* substances. These are Sugar, Sodium chloride, Water, Calcium, Potassium etc.

(b) **No-Threshold or Non-Threshold Substances :** The substances which after their filtration through the glomerulus are not reasorbed back into the blood, but are excreted out of urine are known as *No-Threshold* or *Non-Threshold* substances. They are waste products or other substances of no use to the body economy and not reabsorbed under any circumatances. These are urea, uric acid, creatinine, ammonia etc.

(c) **Ethereal Sulphate :** This is indican with is an index of intestinal putrefaction and signifies protective synthesis in the liver. It gives an indication of the extent of detoxication of Indole and Phenol.

(d) **Reaction of Urine :** The urine is acidic in reaction due to the presence of acid sodium phosphate and organic acids like lactic acid oxalic acid, hippuric acid etc. The pH of urine becomes 6.

(e) **Nitrogenous Equilibrium :** When an individual is losing in his urine an amount of nitrogen equal to that which he is absorbing, he is said to be in nitrogenous equilibrium. In this condition, all the nitrogen lost from his tissues is being exactly replaced after ingestion of large quantities of protein.

CHAPTER TEN

NERVE MUSCLE PHYSIOLOGY

Introduction : The nerve muscle physiology concerns about the physiology of muscle and nerves. The nervous tissue is one of the main elementary tissues of the body and develops from ectoderm. The function of the nervous tissue is to transmit electrical messages from one part of the body to another. To this end nerve cells are elaborately interconnected, the processes of one cell linking up with adjacent cells. Nervous tissue is an intricate network of interconnected cells whose function is to transmit and sometimes to store information. The muscle forms the main bulk of the body and covers the internal structures like nerves, arteries, veins, etc. of the body. There are three types of muscular tissue known as visceral, skeletal and cardiac. The visceral muscle consists of sheets of densely packed, elongated fibres running parallel to each other and bound together by connective tissue. It is controlled by the involuntary part of the nervous system. The visceral muscle contracts, fatigues and comparatively slowly. The skeletal muscle is associated with the skeleton and cardiac muscle with the heart. Both appear characteristically striated when viewed under the microscope and both contain contractile fibrils. The skeletal muscle is controlled by the voluntary part of the nervous system and provides the basis of all voluntary movement in the body such as locomotion and movement of the limbs.

Q. 1. Describe the chemical composition of the Nervous Tissue.

The nervous tissue is one of the main elementary tissues of the body and develops from ectoderm. Structurally, this tissue consists of neurone and neuroglea. The nervous tissue is slightly alkaline in reaction in the living resting state but it becomes acid during activity and after death. The cholesterol and phospholipide content become high in the nervous tissue. The average composition of the white and gray matter of the nervous tissue are the following :

Water : The gray matter contains 84% water and white mater contains 70% water.

Solids : The gray matter contains 16% but white matter contains 30% solids.

I. **Protein :** The gray matter contains 8% but white matter contains 10% protein. It includes globulins, nucleoproteins in the nerve cells and neurokeratin in the myelin sheath.

II. **Fats :** The gray matter contains 4·4% but white matter contains 13·5% fats. These include phospholipides (lecithin, cephalin and sphingomyelin), cholesterol and traces of neutral fats.

III. **Carbohydrates :** The gray matter contains 3% and white matter contains 5% carbohydrates. These include cerebrosides or galactosides (Phrenosin, Kerasin, Nervone and Hydroxynervone) and traces of glucose and glycogen.

IV. **Inorganic Salts :** The gray matter and white matter contains 0·8% inorganic salts individually. These include mainly potassium salts but also contain sodium, calcium and traces of other inorganic salts.

V. **Extractives :** They are found in traces in white and gray matter of the nervous tissue. These include ammonia, lactic acid, creatine phosphate and adenyl pyrophosphate etc.

Q. 2. **Describe the properties of Nerve Fibres. How the nerve fibres are classified ?**

The nerve fibres are one of the component of a neurone. They help in the process of receiving and transmitting nerve impulses.

Properties of Nerve Fibres : The nerve fibres show a number of physiological properties which are as follows ;

(a) **Excitability :** The nerve fibre can be stimulated by mechanical, thermal or electrical stimulus. When a nerve fibre is electrically stimulated, there will be the observation of polarisation, depolarisation,monophasic and diaphasic variations. The excitability of nerve fibres depend upon the strength of the stimulus, duration of stimulus, direction of the current, frequency of stimulus and injury.

(b) **Conductivity :** The nerve impulse is conducted along the nerve fibre. The conductivity shows the propagation of impulse along a nerve in both directions and velocity of nerve impulse. The factors affecting conductivity are temperature, mechanical pressure, multiple stimuli, blood supply, different chemicals, H-ion concentration, ionic effect and lack of oxygen.

(c) **All or None Law :** If the adequate stimulus is applied, a nerve fibre will always give a maximum response. There will be no alteration of responses take place if the strength or duration of the stimulus be further increased.

(d) **Summation :** The summation of two sub-minimal stimuli is possible in a nerve fibre.

(e) **Refractory Period :** When the nerve fibre is once excited, it will never respond to a second stimulus for a brief period. The period is known as "Absolute Refractory Period".

(f) **Adaptation :** The nerve fibre quickly adopts itself and there is no excitation during the passage of a constant current.

(g) **Accommodation :** If a stimulus with stronger strength is applied very slowly to a nerve, then there is no response due to lack of attaining the threshold strength.

(h) **Indefatigability :** Nerve in infatiguable. If the nerve is stimulated repeatedly, the muscle fails to give any response but the isolated muscle when stimulated, it is excited which proves that nerve is in fatiguable.

Classification of Nerve Fibres : The nerve fibres may be classified as :

I. **Functionally** : The nerve fibres have been classified as Motor or efferent nerves, Sensory or afferent nerves and Autonomic nerves.

(1) *Motor or Efferent Nerves :* They carry motor or volitional impulses from the motor area of the brain and propagate it to the muscle or muscles concerned so as to execute a particular act of movement.

(2) *Sensory or Afferent Nerves :* They carry different kinds of sensory impulses from the periphery and having passed through different cell stations are finally distributed to the different sensory areas of the brain. The *nerve of general sensibility* carry pain, heat touch, cold, pressure and deep sensations where as *nerves of special senses* consist of nerve of taste, smell, hearing and vision.

(3) *Autonomic Nerves* : They are automatic in action and are not controlled by will. They consist of *sympathetic* and *parasympathetic nerves.* The sympathetic nerves of the heart cause it to contract but the parasympathetic nerves of the heart cause it to relax. Of the autonomic nerves that which causes contraction is known as the *effector* or *acceleratory nerve* and that which causes relaxation is known as the *inhibitory nerve.*

II. **Histologically** *:* The nerve fibres have been classified as medullated and non-medullated nerve fibres.

(1) *Madullated Nerve Fibres :* They possess medullary sheath such as the nerve fibres when they come out of the gray matter of cerebrum, the pre-ganglionic fibres of the autonomic nervous system etc.

(2) *Non-Medullated Nerve Fibres* : They posses no medullary sheath such as the nerve fibres inside the gray matter of cerebrum, the post-ganglionic nerve fibres of the autonomic nervous system, etc.

III. **According to the Diameter of the Nerve Fibre** : The physiological properties of nerve fibres vary with their diameter and the rate of conduction of impulse. There are three groups of fibres known as **A, B** and **C.**

1. "A" *Fibres :* These are α, β, γ and δ types. They have thick myelin sheath and the velocity rate becomes 30 to 120 metre per second. The height of the spike potential is directly proportional to the diameter of the fibre. These fibres develop negative after potential and serve neo-sensibility sensations like touch, kinaesthetic pressure etc. These group of fibres are the thickest fibres and motor fibres and few sensory fibres belong to this group.

2. "B" *Fibres* : They possess thin myelin sheath having the velocity rate becomes 10 meter per second. The conduction velocity is directly proportional to the fibre diameter. The height of the spike potential to the diameter of the fibre. These fibres no negative after potential and serve paleo-sensibilty like temperature sensation. These group of fibres are most of the sensory fibres and pre-ganglionic autonomic fibres.

3. "C" *Fibres* : They possess no myelin sheath having the velocity is directly proportional to the fibre diameter. The height of the spike potential if directly proportional to the diameter of the fibre. These fibres develop negative after potential and carry visceral pain sensibility. These group of fibres are the thinnest fibres and post-ganglionic autonomic fibres belong to this group.

Q. 3. Describe the Transmission of Nerve Impulse.

The nerve impulse is a self propagated electro-chemical change which is transmitted by nerve fibre and it involves an alteration in electrical state and chemical changes. The chemical changes in nerve fibre are propably concerned with recovery processes which follow activity. The development and propagation of the nerve impulse are probably represent the essential process involved in transmitting the impulse along the fibre. The nerve is a cylinder of axoplasm contained in a cell membrane surrounded by a fluid containing NaCl and other salts. The cell membrane is fairly resistant to the passage of all ions. K^+ and Cl^- are relatively diffusible and may enter and leave the cell but Na is not and remains outside.

Component : The different component of the nature of nerve impulse are : (1) Nature of change arise at the spot of a nerve fibre where stimulated. (2) Nature of propagation of the excitable change through the nerve, synapse and motor end-plate.

Features of Nerve Impulse :

(a) **Polarisation :** Nerve is considered to be charged positively and negatively of its outer and inner surface respectively of its sheath which consist of two layers and they are all equipotential condition which is known as *polarisation* and there is no E. M. F.

(b) **Depolarisation** : Any stimulus either chemical, electrical or thermal causes change in permeability and there is negative ion flows to the outer surface producing negative spot as contrast to the remaining which is positive ion. This is known as *depolarisation*.

(c) **Action Potential or Action Current :** There will be sign of deflection in the galvanometer due to changed E. M. F. i.e. charge flows from positive to the negative side which is here scientifically a sign of production of energy after conserve either chemical, thermal of a same nature of electrical which was applied as stimulus. This flow of current is known as *action potential* or *action current*. The tendency of K^+ to flow out, together with the indiffusibility of the anions, generates across the membrane a potential difference of 70 mV. which is just what is needed to maintain the high internal concentration of K^+ and low internal concentration of Cl^-.

(d) **After Potential:** The action potential of the vertebrate nerve does not normally show the large overshoot beyond the resting value seen in the giant fibre. The tail of the action potential, which is called the *after-potential*, is very small in fresh nerve but is much large in conditions associated with the super-normal phase of recovery.

(e) **Refractory Period:** The point of the spot in a nerve so long remain in depolarised condition which is due to stimulation can not be stimulated by second stimulus which is known as *refractory period*. At the tail of the action potential wave, the potassium conductance has greatly increased, a given depolarizing stumulus will tend to leak through the sheath without depolarizing it much.

Theories Concerned: Several theories have been advanced to explain the nature of nerve impulse but none of them come into final conclusion.

(a) **Membrane Theory:** In this theory, the action potential helps in the conduction of nerve impulse. The membrane surrounding the nerve fibre remains polarized the nerve fibre is at rest. During stimulation of nerve fibre, the membrane becomes permeable and thereby the distribution of ions on either side of the membrane become redistributed and the membrane becomes depolarised. The action current from the unstimulated positive spots will flow through the nerve sheath. The current of action stimulates the next adjacent segment of the nerve fibre and in this way the impulse travels on.

(b) **Neuro-Hormonal Theory:** The conception of neuro-hormonal theory is based on alteration of K-ion concentration outside and inside of axis cylinder of a nerve fibre. Normally, potassium is highly concentrated in the nerve matter than outside. This stimulus which causes depolarisation also produces K-ion outside which is a initiating factor as regard the synthesis of *acetyl choline*. In the meantime while polarisation has taking place, potassium ion flows in which it does not allow acetyl choline to stay but destroyed by the choline esterase. So, we see that with the advancement of depolarised point of the outer surface of nerve and followed by polarised point.

Transmission of Nerve Impulse: The electrical charge which is positive one that flowing to the negative side, some energy is being spent in order to flow to negative side resulting negativity at the next spot. In this way the negative point are advancing on the outer surface of nerve fibre which is known as *transmission* or *propagation of nerve impulse*. At the same time simultaneously the-ve point becoming +ve which can be more clearly stated that propagation of nerve impulse consists of advancement of the polarised point and go forward to the periphery.

The condition through the synapse has been observed. The rate of conduction of nerve impulse differ at the synaptic region than in the nerve which is here lesser due to the fact that this is the anatomical continuity and no oxidative material produces less available energy and thereby there will be less conduction.

The extra-time is required for passing acetyl choline which flows out from dendron to axon and axon to dendron. It acts as chemical stimulus and thereby conduction of next impulse travels to the next neurone. It has been observed that the conduction through the synapse is in lower rate through the conduction of motor end plate and neuromuscular junction.

Q. 4. What are the changes of the nerve fibre when it is electrically stimulated ?

The nervous system constitutes the neurone and neuroglia. A neurone is the structural and functional unit of the central nervous system. It is made up of a nerve cell and nerve processes. The nerve processes are the dendrons that constitute the receiving numerous shorter fibres and the axons or axis cylinder that constitutes the single large transmitting, fibre.

Electrical Changes of the Nerve Fibre : The nerve fibre after electrical stimulations has got different types of manifestations, are the following :

I. **Current of Injury or Demarcation Current :** The injured surface of the nerve becomes electro-negative to the uninjured part. If the electrodes of a galvanometer are connected with the injured and the uninjured spots a current flows in the nerve from the injured to the uninjured part which is known as the *Current of Injury* or *Demarcation Current*, whereas outside the nerve the current travels in the reverse direction.

II. **Diphasic Variation or Current of Action :** When two points on the uninjured surface along the nerve are conneted by the two electrodes of a galvanometer and then an electrical stimulus is applied on the nerve beyond the two poles, it will be observed that the galvanometer needle at first deflects to one side and then to the opposite side of the zero line and ultimately comes back to the resting position. The negative potential overtakes the first electrode and then the second electrode and the current through the galvanometer flows in the reverse direction. This is called *Current of Action* or *Diphasic Variation* due to the two way movement of the galvanometer.

III. **Monophasic Variation :** When one of the two electrodes is placed on an injured surface along a nerve, the current of action approaches the injured surface and becomes neutralised by the current of injury, thus exhibiting a condition called *Monophasic Variation*.

IV. **Electrotonus :** When a constant current is allowed to pass through the nerve of a nerve muscle preparation, maximum alteration of excitability and conductivity is found to take place in the cathode and anode regions. This type of electrical changes is known as *Electrotonus*. That around the anodal region is known as *Anelectro-*

tonus and that around the cathodal region is known as *Catelectrotonus*.

Q. 5. How will you measure the Velocity of Nerve Impulse ?

When something travels down the nerve from electrodes to muscle, it must take a certain time to arrive. The interval between the shock and the beginning of muscular contraction will clearly be greater if the electrodes are at the far end of the nerve. The measurement of the velocity of nerve fibre was first made by *Helmholtz* both in frog and man. The velocity of nerve impulse is depedent on the diameter of the fibre, the larger-fibres conducting more rapidly. The velocity of conduction of an impulse in toad's sciatic nerve is by temperature.

Procedure : (1) Prepare a nerve muscle preparation preserving the entire length of the nerve from the spinal column to its attachment with the muscle. (2) Get the drum smoked and arrange drum to move fastest in rapid gear and arrange as for simple muscle curve. Two electrodes from Pohl's commutator, which is connected to two terminals of secondary coil, should be arranged and the sciatic nerve will rest on the two electrodes placed at two extremites of the nerve. (3) Take a curve when electrode at, say, the furthest end of the nerve is active. Get another curve when the nearest electrode is active by being connected to secondary by movement of the key of the commutator. (4) Take two muscle curves on the same base line. Take the point of stimulus, which is same in both the cases and a time tracing. (5) Measure the length of the nerve between two electrodes and calculate the difference in latent periods of two curves. Thus calculate the velocity of nerve impulse in metres per second.

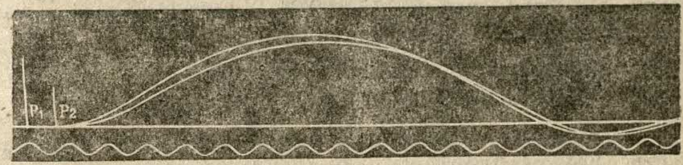


Fig. 34. Graphic Record of the Velocity of Nerve Impulse.

Reading : The rate of propagation of nerve impulse at ordinary room temperature in toad's sciatic nerve is normally about 25 metres per second, 60 metres per second in the motor nerve in man and in warm blooded animals, it is 90 to 120 metres per second.

Calculation : The velocity of the transmission of nerve impulse becomes $\mathbf{V}=\frac{S}{t}=\frac{\text{Space traversed}}{\text{Time taken}}$. By putting the values for "S" and "t" experimentally obtained we can find out the value for "V".

[10 **Q. 6. Describe the Degeneration and Regeneration in the Nerve Cell.**

A neurone is the structural and functional unit of the central nervous system. Each neurone is made up of a nerve cell and the long and short process known as axon and dendron respectively. The nerve cell contains central nucleus, mitochondria, golgi apparatus, Nissl bodies, neurofibrils and pigments. The centrosome is absent in a nerve cell and so the power of cell division is lost and the replacement is done by the proliferation of neuroglia and the process is known as gliosis. The nerve cell due to different unavoidable conditions, becomes in a way of degeneration and regeneration.

Degeneration of the Nerve Cell : It is a process by which a nerve cell becomes ruined or destroyed. The changes begin within 48 hours of the section of the nerve fibre.

(a) **Chromatolysis :** It is a phenomenon by which Nissl bodies are disintegrated and disappeared into a fine dust which may lose its staining reaction by 15 to 20 days. The chromophil substances are scattered and there will be swelling and vacuolization of the cell. The causes of chromatolysis are : (1) Due to cutting of the nerve fibre within 48 hours. (2) Due to exhaustion and intoxication such as in extreme fatigue condition. (3) Decreased blood supply. (4) In hyperpyrexia i.e. brief exposure to 109°F causes coagulation of the substance. (5) Action of certain nerve poisons.

(b) **Change of shape of the Cell body :** The cell body which is polygonal in shape becomes round or oval.

(c) **Fragmentation of Golgi apparatus :** The golgi bodies and mitochondria become fragment and dwindle in amount due to increased fluid content.

(d) **Disappearance of Neuro-Fibres :** The cell swells up after drawing more fluid and becomes rounded and the neurofibres are fragmented and gradually disappeared and removed from the cell body.

(e) **Displacement of Nucleus ;** The nucleus is displaced to cell dies and finally disappears. The cell body with nucleus becomes shrunken in volume.

Regeneration of the Nerve Cell : It is a process of repair or regain or reconstruction of the lost contents of the cell. The reapperance begins in 20 days and is completed by 80 days. The process of reappearance of the lost structure are : (1) The Nissl granules and golgi apparatus gradually reappear. (2) The cell regains its normal size. The cell body which becomes round or oval during regeneration becomes polygonal in shape. (3) The nucleus returns to its original central position from eccentric condition. (4) The neurofibrils and mitochondria will reappear.

Q. 7. Describe the histological structure of a Medullated and Non-Medullated nerve fibre. Discuss the degeneration and regeneration of the Nerve. What is Reaction of Degeneration ?

A neurone is the structural and functional unit of the central nervous system. Each neurone is made up of a nerve cell and the long and short processes known as a axon and dendron and transmits the same impulse through its axon to other cells.

Structure of Medullated Nerve Fibre : The medullated nerve fibre consists of an unbroken nucleated, tubular *Neurilemma Sheath* or *Sheath of Schwann* which lies superficial to the myelin sheath. It has got protective function and it also helps in the regeneration of the nerve fibres after degneration. The *Myelin sheath* is a higly refractile, whitish double contour sheath closely invest the axis-cylinder process and is responsible to give the white colour to a nerve. The important constituents of myelin sheath are cephalin, lecithin and phosphoric acid. The *Axis cylinder* is situated below myelin sheath which is made up of series of parallel axis fibrils enclosed by *Axoplasm* and covered by *Axolemma*. The axoplasm consists mainly of a solution of K^+ ions held by electrical attraction to organic actions of which the membrane is impermeable. The point where the myelin sheath is deficient, is known as *Nodes of Ranvier* and the segment of the nerve in between the two Nodes of Ranvier, is known as *Internode*. In between the two nodes of Ranvier, there is a single cell just underneath the neurilemma sheath, is called *Cell of Schwann*.

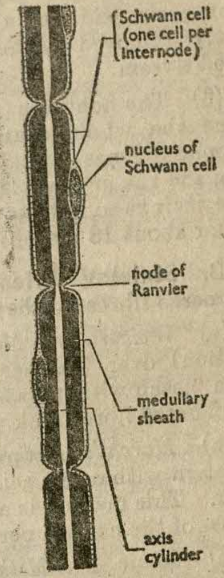


Fig. 35. Structure of a Medullated Nerve Fibre.

Structure of Non-medullated Nerve Fibre : The non-medullated or amyelinated nerve fibres have *no myelin sheath*. It is composed of *neurilemma*, *cell of Schwann*, *axis rod* with *axolemma*, *axoplasm* and *axis fibrils*.

Degeneration of the Nerve Fibre : The process of degeneration sets in the with 24 hours and on the third day, the fibre ceases to conduct impulses. Degeneration is completed in three weeks. For a few millimeters on either side of the the cut fibres, there are acute changes known as traumatic degeneration but the peripheral portion also simultaneously along its whole length, the change of secondary or *Wallerian degeneration* which commence in the first hour and progress to complete degeneration in few days. In Wallerian degeneration, the Schwann cells and the connective tissues remain and undergo changes anticipatory of re-innervation. Following changes in the nerve fibre during the process of degeneration are :

A. **Histological Effects :** (1) The appearance of swellings and fusion take place in the neurofibrils. There will be twisting and irregular thickenings of the axis cylinder and shortly afterwards, the axis cylinder breaks up irregularly into short length. The fragments are taken away by the macrophages or R. E. cells.

(2) The Myelin sheath of the medullated nerve fibre becomes swollen and breaks up irregular fatty oily droplets of varying size and undergoes chemical changes along which the liberation of highly unsaturated fatty acids take place. The lecithin of the sheath is broken down into glycerol, saturated and unsaturated fatty acids, phosphoric acid and a nitrogenous base known as choline. They are partly removed by the macrophages and partly washed out in the blood stream.

(3) The Schwann cell at first proliferate, then divide mitotically along the whole course of the peripheral stump and increase the cytoplasmic mass of Schwann cell which gradually fills the neurilemmal tube and the process is completed by three months. The peripheral tube shrinks to half its original diameter in 7 weeks and may remain so far about 18 months.

B. **Staining Effects:** It is one of process by which degenerative nerve fibres can be tested.

(a) *Weigert-Pal Method:* Fix Muller's fluid (weak bichromate solution) over the nerve fibres and overstain with haematoxylin. Then bleach with potassium chromate solution in sulphuric acid. The degenerated fibres look yellow but the normal fibres look blue.

(b) *Marchi's Methed:* Fix the nerve fibres in Muller's fluid and stain with osmic acid. After staining, the degenerated fibre looks black. This method is a fact of great importance for mapping out the tracts of the central nervous system.

(c) *Osmic Acid Method:* The normal medullated nerve fibres stain black with osmic acid which is reduced to the black osmic oxide.

C. **Physiological Effects:** These effect depend on the types of nerve fibres involved;

(a) *Sensory Nerve*; (1) Loss of sensation conveyed by that particular nerve which is stained with Muller's solution. (2) Loss of tone of muscle of corresponding segments. There will be twisting and irregular thickenings of the axis cylinder. (3) There will be tropic ulcer caused as a result of loss of sensation.

(b) *Motor Nerve:* If the motor nerve fibre is cut peripherally, there will be: (1) Loss of tone of the muscles or flaccidity. (2) Wasting of the muscle proper. (3) Loss of all types of jerks like knee-jerk, tendon-jerk, ankle-clonus and Babinski's sign. (4) Reaction of degeneration is present.

D. **Transneural Degeneration:** The nerve impulse is carried from one neurone to other which forms neuro-neural junction. There is no actual anatomical continuity at this synaptic junction. It is observed that the section of one neurone causes degeneration of the next neurone as well. This is called transneural degeneration. In many conditions, this type of degeneration occurs. e.g. (1) Section of upper motor neurone leads to the degeneration of anterior horn cells. (2) Section of the optic tract sometimes leads to the degeneration of the cells of lateral geniculate body. (3) After section of posterior spinal root, the posterior horn cells degenerate. (4) After section of motor cortex or pyramidal tracts, the anterior horn cell many degenerate.

Regeneration of Nerve Fibre : It takes place only outside the central nervous system where neurolemma is present which is essential for the process of regeneration. The regeneration of the central axon of the dorsal nerve root may occur as far as the piamater but there is no penetration into the spinal cord. It may arise from the portion of the cut nerve still connected to the cell body. If the peripheral nerve fibres are cut, regeneration of the nerve fibres will take place. The following processes are observed during regeneration of the nerve fibre :

(1) There will be downward growth of the neuro-fibrils from the proximal segment. The cell of Schwann due the chemotatic property will attract the sprouting neurofibrils into the distal neurilemma tube. Near about 100 neurofibrils will appear in the distal neurilemma tube of which 99 will disappear and the central one will persist which will gradually hypertorphy and will take the function of axis cylinder. The rate of growth of the neurofibrils in the distal neurolemma tube is 2·5 m m. per day or 24 hours. As there is downward growth of the neurilemma sheath of the distal cut segment and it will join with the proximal cut segment.

(2) The medullary sheath begins to develop in about 15 days and proceeds periphery along the fibre. The different components of myelin sheath are derived from the disintegrated cell of Schwann.

(3) A small parent nerve cell gives rise to a fine fibre develops a thick fibre which ultimately form a neurilemmal tube.

(4) The presence of Schwann cell is essential for regeneration. Most of the cell of Schwann will disintegrate and disappear and single cell of Schwann will persist which will occupy the original position. The nerves which do not possess cell of Schwann, there will be no regeneration occur and therefore optic nerve and other white matter of the central nervous system do not regenerate at all.

The process of regeneration will not occur in the following conditions : (1) Absence of Neurilemma sheath. (2) If the gaps between the cut segments are wide enough. (3) If the gap between the two cut segment is intervened by any foreign body.

Reaction of Degeneration : When the motor nerve to a muscle is cut, it undergoes degeneration after sometime and ceases to function. Tha muscle chronaxie rapidly increases and the briefly acting Faradic current is ineffective to excite the muscle. This is called reaction of degeneration which consists of : (1) The normal heathy muscle will contract both by Galvanic and Faradic currents but atrophied, muscle will contract only by Galvanic current and never by Faradic current. (2) In normal healthy muscle, K.C.C. (Cathode Closing Contraction) is greater than A C.C. (Anode Closing Contraction) but in atrophied muscle, A.C.C. become greater than K.C.C. or in other words, qualitafive alterations in irritability of the muscle is present. (3) A "slow worm-like" contraction with Galvanic current.

Q. 8 Describe the Composition of Muscle.

The muscle form the main bulk of the body and covers the internal structures like nerves, arteries, veins etc of the body. According to the mode of function, muscles are classified into voluntary, involuntary and cardiac.

Physical Properties of Muscle : The physical properties of muscle are as follows :

(1) *Density* : It is 1·062 g. per ml.

(2) *Diffusion Constant of Oxygen* : It becomes 0·14 ml. per minute for 1^2 cm. area.

(3) *Thermal Conductivity* : It is $1{\cdot}18 \times 10^{-3}$ Cal. per minute for 1 Cm^2 area.

(4) *Thermal Capacity per gram* : It becomes 0·88 Cal. per degree centigrate.

Chemical Composition of Muscle :

Water : 75%
Solids : 25%

I. **Proteins :** 20%. It includes Albumins (Myogen and myoalbumin), Globulins (Myosin and globulin X) nucleoprotein, collagen, elastin and myohaemoglobin. The actin complex are the actomyosin, tropomyosin A and B, troponin, α-actinin, β-actinin, G-actin, F-actin, tropomyosin are present in the muscle. Several other protiens like Component-C, delta protein, metamyosin, contractin, X-protein, Y-protein are present in the muscle.

II. **Fats :** 0·2%. It includes cholesterol, lecithin and neutral fat.

III **Carbohydrates** : 1%. It includes Glycogen, 0·5 to 1·0% and Hexose mono-phosphate, 0·05%.

IV. **Inorganic salts** : 1·0 to 1·5%. It constains phosphates, sulphates and bicarbonates of Na, K, Ca, Mg, Fe and chloride.

V. **Extractives :** (*a*) **Non-nitrogenous** : It contains Lactic acid, 0·02% and Inositol, 0·25%. (*b*) **Nitrogenous** : (1) Adenosine-Triphosphoric acid (ATP) 0·25%, Adenosine-diphosphoric acid (ADP) and Adenosine-monophosphoric acid (AMP) 0·15% (2) Creatine Phosphate or Phosphagen, 0·5%. (3) Xanthine, Hypoxanthine and Inosinic acid. (4) Carnosine, Anserine and Carnitine.

VI. **Pigments :** These include Myohaemoglobin in red muscle, Cytochrome a, b, c and Flavines.

VII. **Enzymes and Co-enzymes :** These include Phosphorylase, Phosphoglucomutase, Aldolase, Triose-phosphate dehydrogenase, Transphosphorylase, Enolase, Aconitase, Malic dehydrogenase, Adenosine-triphosphatase, Deaminase etc.

Q. 9. Describe the Properties of Skeletal Muscles.

There are three types of muscles in the body which are skeletal or voluntary, plain or smooth and cardiac muscles. The skeletal muscles are attached to the bones by tendons. The different types of properties of skeletal muscles are the following :

I. **Excitability and Contractility :** The skeletal muscles are excitable by the application of any types of stimulus like mechanical, thermal, chemical or electrical. The muscles after excitation are immediately followed by relaxation.

(*a*) **Effect of Single Induction Stock :** A single induction shock will produce a single contraction and the record on a moving drum will produce a **simple muscle curve.** The record of isotonic contraction of toad's gastrocnemius muscle has a total duration of about 0·1 second. The simple muscle curve consists of three parts : (1) *Latent Period* : It is a distance between the point of stimulus and point of commencement of the contraction of muscle. It includes time for propagation of impulse along the nerve fibre and delay of the transmission of impulse at the myoneural junction and instrumental inertia. It occupies 0·01 Sec. (2) *Period of Contraction* : From the point of commencing contraction to the highest point of the curve is known as period of contraction. The contraction is at first very rapid, but then progresses more slowly to its maximum. It occupies 0·04 Sec. (3) *Period of Relaxation* : From the highest point of contraction to the point of which the lever again reaches the abscissa line is known as period of relaxation. It occupies 0·05 Sec.

(*b*) **Effects of Two Successive Stimuli :** The changes occur in the different features of a simple muscle curve as a result of application of two successive stimuli before the contraction caused by the first one has ceased. The following phenomena are observed by repeatition of stimulus. (1) *Staircase phenomenon* : When a muscle is repeatedy stimulated at an intervals of certain seconds, the first few contractions become gradually higher just as stair-like rise and it is known as staircase phenomenon. (2) *Clonus* or *Incomplete Tetatus* : When repeated maximal stimuli are applied and the individual contractions are discernible and the record will show a series of wavy oscillations. (3) *Tetanus* or *Compound Contraction* : When a muscle receives a series of rapidly repeated stimuli, it remains in a condition of contraction as long as the stimuli are sent in or until it looses its irritability from the effect of fatigue. The distinctive sign of tetanous is the more or less complete fusion of the contractions due to the seperate stimuli. The phenomenon of summation is the total shortening of the muscle in tetanus may be considerably greater than that caused by a maximal simple contraction. (4) *Fatigue* : It is the progessive loss of excitability appearing in the muscle after its repeated activity. In this condition, the muscle is unable to contract after the application of stimulus due to the accumulation of acetylcholine and adrenaline in the neuro-muscular junction or synapse.

(*c*) **All-or-None Law :** If a muscle fibre contracts at all, it will contract to its maximum limit provided the conditions remain constant. If the conditions are changed, the amount of contraction of a muscle vary.

(*d*) **Effects of Load** : When the muscle is allowed to lift increasing grades of loads of stimulation, the changes affect the shape of the simple muscle curve. It is also studied the amount of work done by the muscle and it is also observed the efficiency of the muscular contraction under different circumstances. The amount of work done by the muscle during its contraction is equal to the product of the load and the height to which it was raised. The actual work is calculated by multiplying the weight lifted by the distance from the axis to the point of the suspension of the weight, divided by the distance from the axis to the point of attachment of the muscle. Suppose the fraction was $\frac{1}{5}$ and the actual load lifted 6 grams. The height to which it was raised was 4 m.m. ; consequently the work performed was 24 gramme millimeters.

(*e*) **Effects of Temperature** : The changes affect the latent period, the period of contraction, the period of relaxation and the amplitude of the curve when the muscle is made to respond after treating by a bath in salines of different grades of temperature. The different effects of temperature on the isotonic contraction of toad's gastrocnemius muscle are as follows : (1) As temperature rises, the latent period gradually decreases and the period of contraction becomes markedly shorter. (2) The period of relaxation varies as that of contraction but to a more marked degree. (3) The height of contraction is higher in the warmer curves whereas it is lower in cold one. (4) Too much heat (above 40°C) induces heat rigor due to the coagulation of muscle proteins.

(*f*) **Effects of Salts and Ions** : (1) *Sodium* salts exert an excitatory effect upon skeletal muscles. (2) *Calcium* salts are depressant and neutralise the effect of sodium. (3) *Potassium* salts reduce excitability and help in quick fatigue formation. (4) *Magnesium* ion is essential for the action of phosphorylase enzyme which transfers phosphate during muscular contraction. (5) *Barium* salts produce prolonged muscular contracture. (6) *Increased H-ion* reduces excitability of muscle and hasten fatigue.

II. **Refractory Period :** After the application of first stimulation upon muscle, there is a brief period during which the muscle is not excitable to a second stimulus, is known as "*Refractory Period*". The refractory period is very short and falls within the latent period in case of voluntary muscles. The refractory period is lengthened in cold and shortened in heat enviornment. It is about 0·005 second in the skeletal muscles of frog and about 0·002 second in the mammalian muscles.

III. **Tonicity :** The tone of a muscle is the readiness and steadiness of a muscle to perform motor activity after receiving sensory impulses. The tone is absent in an isolated muscle. The muscle tone is a reflex process and the reflex centres are situated in the spinal cord. The muscle fibres contract in groups. When one group of muscle fibres contract and the other group relax and thereby the whole muscle does not show any fatigue.

IV. **Conductivity :** When muscle is stimulated, the wave of contraction starts at the point of stimulus and is propagated in both ways along the muscle fibres. The rate of propagation is 3 to 4 metres per second in frog's muscles and 6 to 12 metres per second in warm-blooded animal.

V. **Extensibility and Elasticity :** Muscle extends after stretching but it comes back to its original length in a little slower rate after releasing the tension. When the muscle does not immediately come back to its original length after releasing the tension, is known as *Contraction remainder*. This contraction remainder is a form of contracture produced by the residual shortening due to the sluggish relaxation of a muscle after its contraction. It is produced due to absence of reserve A.T.P., phosphagen and glycogen, partial block of oxygen and accumulation of lactic acid.

Q. 10. Describe the properties of Plain Muscles.

The properties are not identical in all smooth muscles and depend on the site where each lies.

I. **Contractility :** The contraction in plain muscle is sluggish, as compared with the striated muscle, having lost latent period and prolonged stages of contraction and relaxation. This varies with different muscles and in different animals.

II. **Excitability :** The excitability of plain muscle is less than that of the skeletal muscle as exhibited by its respose to electrical stimulation.

III. **Rhythmicity :** When stretched the smooth muscles show normally intermittent rhythmic contractions and the strength and frequency of which vary under different conditions. The rhythmic contractions are observed in strips of the inner wall of intestine composed of smooth muscle and devoid of nerves.

IV. **Conductivity :** The wave of contraction is propagated along the whole muscle fibre. The rate of propagation is much slower.

V. **Tonicity :** The plain muscle remain in a state of light tension. The tonicity occurs at no expense of increased energy, nor with apparent manifestation of fatigue but through a change in its velocity for maintenance of tonus, oxygen is necessary as it preserves the cellular structure. Such tonic contraction of uterus helps in stopping heamorrhage after expulsion of the foetus from it.

Q. 11. Compare the different characteristic features of voluntary, Involuntary and Cardiac muscles.

The muscles form the main bulk of the body. It controls the movement of the different parts the body by the process of alternate contraction and relaxation and thereby contractility is the inherent property of all types of muscular tissue. Functionally, tissue can be divided into voluntary, involuntary and cardiac muscles. The voluntary muscle concerns with movements of the body controlled by will, the involuntary muscles act independently without having any volitional control but cardiac muscle though possess a contractile network like cellular syncytium, help for the origin and propagation of cardiac impulse with the help of special junctional tissues. The main characteristic difference of three major types of muscles are summarised below :

I. Histological Difference.

Points of difference,	Voluntary	Involuntary	Cardiac
1. Size and Shape.	Fusiform, $1''$ long, $\frac{1}{5000}''$ broad.	Similar but smaller.	Cylindrical in longitudinal section but polyhedral in tranverse section.
2. Sarcolemma, sarcostyles and sarcomere.	Present and complete.	Ill-defined or absent.	Ill-defined or absent and incomplete.
3. Fibres.	Cylindrical and covered by sheath.	Spindle-shaped and ill-defined.	Quardangular and ill-defined.
4. Intercellular substance.	Minimum and not bridged across by fibrils.	More and bridged across by fibrils.	More and bridged across by fibrils from cell to cell.
5. Striations.	Transverse.	Longitudinal.	Both longitudinal and transverse but all incomplete.
6. Nucleus.	Multiple, eccentric and under the sarcolemma.	Single, placed at the centre of the fibre with distinct nucleoli.	Single and centrally situated.
7. Branching.	Absent.	Absent.	Always branch and unite by their branched neighbouring fibres forming syncytium.

Points of difference	Voluntary.	Involuntry.	Cardiac.
8. Protoplasm.	Granular and present at each pole of the nucleus.	Granular and surrounds the nucleus.	Granular and surrounds the nucleus.

II. Physiological Difference.

1. Rhythmicity.	Absent.	Present.	Present and Characteristic.
2. Refractory period.	Very little.	More.	Greatest.
3. Tetanus.	Possible.	Possible.	Cannot be tetanised.
4. Contractility.	More.	Less.	Less.
5. Excitability.	More.	Less.	Less.
6. Conductivity.	More.	Less.	Less.
7. Automacity.	Increased.	Increased.	More increased.
8. All or None law.	Absent but true for single fibre.	Absent but true for single fibre.	Present because the whole muscle behaves as a single unit.
9. Tonicity.	Depends on Nerves.	Independent of nerves.	Independent of nerves.
10. Peristalsis.	Absent.	Present in hollow viscera.	Absent.

III. Bio-Chemical Difference.

Points of difference.	Voluntary	Involuntary	Cardiac
1. O_2 Consumption.	Can work in anaerobic state for a long time.	Work without oxygen for a certain period of time.	It can consume oxygen 0·56 ml. per gm. per hour.
2. Change of pH.	Stand in a considerable change of pH.	Slight alteration of pH does not affect it.	A little variation of pH causes stoppage of cardiac activity.
3. Lactic acid concentration.	Stand in 2% concentration.	Stand in 2% concentration.	Stand in 0·06% concentration.
4. Glycogen content.	More.	Less.	Not so, except in Purkinje's fibres.

IV. Difference in Composition.

1. Portein.	More.	Less,	Less.
2. Glycogen, A.T,P., Phosphagen and Carnosine.	More.	Less.	Less.
3. Fats.	Mainly neutral fats.	Mainly neutral fats.	Phospholipids and cholesterol maximum.

V. Difference in Ionic Actions.

1. Sodium.	Excitation.	Excitation.	Initiation of heart rate.
2. Calcium.	Depression and neutralises by Sodium effect.	Depression and neutralises by Na-effect.	Increases contraction and duration of systole.

Points of difference.	Voluntary.	Involuntary	Cardiac.
3. Potassium.	Causing less excitability.	Causing less excitability.	Inhibition of contraction producing relaxation.

VI Difference in Distribution and Supply.

1. Distribution.	In the skeletal parts of the body.	Hollow viscera, capsules, skin etc.	Only in Heart.
2. Control.	By will.	Partly by will.	Not at all by will.
3. Arterial Supply.	Peripheral blood vessels.	Branches of the abdominal aorta.	Coronary artery and its branches.
4. Venous drainage.	Superior and inferior vena cava.	Inferior vena cava.	Cardiac veins and its tributaries.
5. Nerve supply.	Cerebrospinal nerves terminating in end-plates.	Autonomic nerves with ganglia and free nerve terminals.	Autonomic nerves ending in a plexiform manner.

Q. 12. What is Fatigue ? What is the cause of production of fatigue ? Where is the seat of fatigue ? Describe the phenomenon of fatigue in muscular contraction graphically. How the phenomenon of fatigue can be studied in Man ?

When a muscle is repeatedly stimulated, a sense of exhaustion gradually occurs and as a result, the latent period and the length of contractions are prolonged, absolute height and the work done by the muscle are diminished and the muscle does not return to its original length. The muscle is said to have the progressive loss of excitability after its repeated activity and fails to react to any further stimulation. This is known as *Fatigue.*

Causes of production of Fatigue : The different factors which are essential for the cause of production of fatigue are the following :

(a) **Muscle glycogen :** The quantitative disappearance of muscle-glycogen supplies a potential energy to the contractile material and if it is lost, it will cause fatigue.

(b) **Waste products :** The accumulation of waste products like lactic acid mainly may reach 0·3% or more in the muscle, cause fatigue.

(c) **Cardiac output :** The high cardiac output causes the venous blood to rush rapidly through the lungs with consquent imperfect oxygenation. It will adversely affect the higher centres and the heart itself impairing their efficiency. The cardiac output thus diminishes and becomes further inadeqate for the needs of the muscle and the body as a whole.

(d) **H-ion Concentration :** The slight rise of H-ion concentration of the blood may depress the brain and cause exhaustion or fatigue.

Seat of Fatigue : The seat of fatigue may be in the muscle, the sensory and motor end plates, the nerve fibres or the motor nerve cells. The end plates are regarded at one of the most important sites of fatigue. The nerve fibres are unfatiguable. The motor nerve cell are the most readily fatiguable point.

Phenomenon of Fatigue : The phenomenon of fatigue can be observed graphically by the effect of excessive repeated stimulation on isotonic contraction on Toad's gastrocnemius muscle. The fatigue is studied in man by an instrument known as *Ergograph* in which a finger lifts a weight over a pulley, and the height to which it is raised is recorded by a marker on a blakened paper over a revolving drum.

Purpose : To study the changes that occur in the different features of a simple muscle curve on repeated application of single induction shocks to a nerve muscle prepation of Toad's gastrocnemius muscle through its nerve.

Procedure : (1) Arrange the apparatus for automatic break shocks. Heavily load the freely weighted lever and do not pour saline on preparation during the experiment. Arrange maximal stimulus through nerve by indirect stimulation. (2) Taken simple muscle curve and without stopping the drum. Take 3 or 4 recordings on the same base line and with the same point of contraction. (3) Then remove the writing lever from the drum by adjusting the myographic

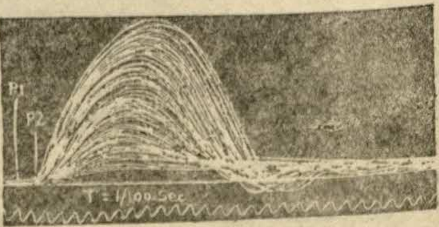


Fig. 36. Graphic Record of the Fatigue Curve. P_1—Point of Stimulation. P_2—Point of Contraction.

stand adjuster without stopping the drum or stopping the stimulation. (4) Count every 25 contractions and again touch the writing lever to the drum rapidly and another recording and contraction. It this way, record every 20th. contraction until the muscle becomes fatigued which is indicated by the failure of the muscle to respond to the stimulus. (5) Proceed thus, recording every 10th. or 15th. curve until height of contraction is negligible. (6) Finally, take point of of stimulus and time tracing.

Findings from the Graphic Record :

(1) The latent period is gradually prolonged, the height of contraction diminishes, the course of contraction is slowed and the period of relaxation is greatly delayed.

(2) Due to successive contraction, there will be loss of excitability and at the same time there is a great deal of relaxation, so that after forty or fifty contractions, several seconds may relapse before the lever returns to the base line. The shortening which remain is spoken of as "*Contraction remainder.*"

(3) When the rate of stimulation is rapid enough to give a tetanus, onset of fatigue is rapid and is shown by a decline in the strength and extent of the tetanus.

(4) The muscle which has been exhaused by repeated stimulation will partially or completely recover by adding normal saline.

(5) Fatigue can be brought about more quickly, if a load is attached to the lever.

Types of Effects after Fatigue :

(a) **Contraction Remainder :** It is a form of contracture by the residual shortening due to the sluggish relaxation of a muscle after its contraction.

(b) **Beneficial Effect :** The increasing height of contraction in the first few curves is ascribed to the "*Beneficial effect*" of previous contraction upon the succeeding one

(c) **Block or Resistance :** It is the temporary stoppage of the transmission of stimulus along the nerve fibre. There are two types of block which are :

(1) *Synaptic block* : It is caused within the synapse due to accumulation of acetyl choline (parasympathetic stimulation and adrenaline (sympathetic contraction). (2) *Neuromuscular block* : It is caused at the neuro-muscular junction due to the accumulation of acetyl choline.

Study of the Phenomenon of Fatigue in Man : The phenomenon of fatigue can be studied in man by an instrument known as Mosso's Ergograph in which a finger lifts a weight over a pulley and the height to which it is raised is recorded by a marker on a blackened surface.

Principle : Fatigue is a state in which the organism is exhausted and requires rest. Therefore, it may be described as a condition of lowered efficiency due to expenditure of energy on work or a decreased capacity for work. The muscular fatigue can be tested by Mosso's Ergograph in which the work is usually carried out by the middle finger of the hand. The amount of work, 'W', for each contraction is the product of the weight 'L' multiplied by the height, 'H' to which it is lifted, ∴ W = L × H. By adding these products together the total work done is obtained.

Instruments Required : The instruments that are generally necessary during this experiment, are the following : (1) Mosso's Ergograph. (2) Kymograph, drum and drum-paper. (3) Weights, stylus and cotton. (4) A metronome. (5) A screen.

Procedure : The Ergographic stage was fixed on the table by means of screw-clamps and the weights were fully suspended over the pulley. A drum-paper was attached to the drum and after being uniformly smoked, was fitted to the kymograph. Then the kymograph was kept horizontally on the table and parallel to the stage and the stylus was properly adjusted. The *metronome* was so adjusted as to give 60 beats per minute. The subject was asked to take his seat comfortably. The forearm of the subject was fixed on the wooden part of the ergographic stage by the belts. Except the middle finger, all other fingers were fastened by belts to the wooden stage. The loop of the rubber band which was in connection with the piston and consequently with the suspended weight, was fastened with the tip of the middle finger. All these were done in such a way that the subject felt no trouble with the pulleying and releasing of the weights by rhythmical contractions and relaxations of the middle finger. A screen was placed in such a way that the subject could not see the record. The subject was asked to pull and releasethe rubber-band rhythmically keeping place with the ticks of the metronome. The subject was directed to do so till he felt complete fatigue. After the record was taken, the smoked paper was varnished.

Findings from Ergographic Experiments : From Ergographic experiments on muscular work, it is learnt the following informations : (1) The sufficient interval between contractions prevents fatigue. (2) The long interval is required for musclar recovery if fatigue sets in. (3) The period of recovery is much prolonged by an effort made to contract a muscle after fatigue. (4) The muscular work becomes diminished with depressed condition of general nutrition of body. (5) The muscular work increases rapidly with supply of food, specially sugar which is soluble and easily absorbable food. (6) The total muscular work is greater with smaller load as fatigue develops less rapidly. (7) The great activity in one group of muscles (i.e. leg muscles in hard walking) diminishes the musclar work in other muscles (i e. arm muscles) due to the accumulation of lactic acid in blood which decreases the work done by other unused muscles. (8) The muscle is not easily fatigued in volutary contractions.

Q. 13. What is "Rigor Mortis" ? Describe the causes and effects of rigor mortis.

Rigor mortis is a state of post-mortem rigidity or stiffening of the muscles after death. The muscle loses its excitability, shortens in length, increases in thickness, loses transluency, becomes distinctly acid and gradually becomes stiff. The rigor mortis starts in the second hour and is composed in three hours after death. It disappears after 24 to 36 hours after death due to autolysis. The caffein, chloroform vapour, increased temperature and acidity will cause quick rigor mortis.

Causes of Rigor Mortis : The different causes that develop rigor mortis are as follows : (1) Complete disappearance of glycogen and formation of lactic acid which may reach 0·5 to 0·65. (2) Complete disappearance of phosphagen or creatine phosphate and formation of phosphoric acid.

Effects of Rigor Mortis : The different types of effects take place in rigor mortis are as follows : (1) There is a gel formation due to the coagulation of muscle protein. (2) The muscle loses its irritability altogether, becomes shortened, opaque and in reaction. (3) Heat is evolved and CO_2 is going out.

Characteristics of Rigor Mortis : The main characteristics of muscle after rigor mortis are : (1) It loses its excitability. (2) It increases in thickness. (3) It shortens in length. (4) It becomes viscous and loses transluency. (5) It gradually becomes stiff. (6) It becomes distinctly acid, the pH will be 5·8. (7) The glycogen content of the muscle disappears. (8) The muscle gives off carbonic acid.

Chemical Reactions taking place during Rigor mortis : Rigor mortis is a stage of permanent irreversible contraction where A.T.P. is deficient and causes establishment of permanent link between actin and myosin. The A.T.P. deficiency fails to bring about dissociation of actomyosin to actin and myosin. When A.T.P. falls 85% and creatine phosphate to 30% of its initial value, the symptoms of rigor mortis bigin to appear.

Q. 14. Describe the different types of changes that take place during muscular contraction.

The muscles form the main bulk of the body and maintain the normal structure and contour of the whole body. In man, there are three types of muscles. The skeletal muscle which the animal uses for its active movements, cardiac muscle which contracts rhythmically throughout life to pump blood around the body and smooth muscle, whose slow contractions cause movements of the viscera. When the muscle has been stimulated, there will be different types of changes such as mechanical or structural, chemical and thermal.

Theories of Muscular Contraction : The different theories about muscular contraction are as follows :

(a) **Older Theories :** These supposed a progressive molecular folding, either ordered or random, with a consequent change in intrinsic mechanical properties, were easier to visualise.

(b) **Sliding Filament Theory :** This leads to a simple explanation of the shape of the tension-length curve of the extended muscle, in terms of the reduced area of contact between actin and myosin.

(c) **Molecular Theory :** A. F. Huxley in 1957, proposes that one type of filament has active groups flexibly attached to it that are small enough to be appreciably displaced by Brownian movement. These groups are supposed to have a higher probability of becoming attached to the other type of filament on one side of their mean position than on the other.

Changes during Muscular Contraction : The different types of changes during muscular contraction are as follows :

I. **Mechanical or Structural Changes :** These type of changes take place when a skeletal muscle is stimulated by a single induction shock either directly or through its nerve. On *Isotonic Contraction*, there will be narrowing of the "I"-band and no change in the "A" band. On *Isometric Contraction*, the shortening of the whole muscle is reduced to a minimum and the tension inside rises. There is no considerable change in width of "A" or "I"-band.

II. **Chemical Changes :** The chemical changes during muscular contraction involves two phases, the anaerobic or contraction phase and the aerobic or recovery phase. The different types of chemical changes that take place during muscular contraction are Adenosine-tri-phosphoric acid, Pyruvic acid and Lactic acid.

III. **Electrical Changes :** Normally, the muscle fibre remain in a state of polarisation. After stimulation, it becomes depolarised and atonce current flow from +ve to −ve side in the outer circuit and in the opposite side direction through the muscle fibres. The various types of electrical changes that take place during muscular contraction are Polarisation, Current of Injury, Monophasic and Diphasic variation, Secondary contraction and All or none law.

IV. **Thermal Changes :** The thermal changes during muscular contraction evolve heat in two stages—the initial heat and delayed heat. The initial heat is slightly aerobic and mostly anaerobic. The delayed heat is mostly aerobic and slightly anaerobic.

Q. 15. Describe the Mechanical Changes (Structural Changes) during muscular contraction.

If a skeletal muscle be stimulated by a single induction shock either directly or by the intermediation of its nerve, it responds by a single short, sharp contraction, followed immediately by a relaxation. In volume, the muscle undergoes a very slight and for most purposes negligible shrinkage, but each muscle fibre and the whole muscle become shorter and thicker. At the same time, if a weight be tide on to the tendon of the muscle, the muscle during contraction may raise the weight and thus perform mechanical work.

Mechanical Changes during muscular contraction: There is shortening of muscle fibres but the thickness is increased. When a muscle fibre contracts, there is an apparent reversal of the dark and light striations and when this contracted condition of the muscle is examined by polarised light, the following things can be noticed :

(a) *On Isotonic Contraction* **:** There will be narrowing of the "I" band and no change in the "A"-band. When the extent of the shortening is great, new changes appear, width of 'A'-band will diminish and 'I'-band more or less completely disappears.

(b) *On Isometric Contraction* **:** In this condition, shortening of the whole muscle is reduced to a minimum and the tension inside rises. There is no considerable change in width of "A" or "I"-band.

Q. 16. Describe the Chemical Changes during muscular contraction.

Muscle does not depend upon immediate oxidative processes to liberate the energy necessary for its contraction. It will continue to contract for sometime in the complete absence of oxygen. The energy stored in glycogen is thus liberated anaerobically. But for the recovery of the muscle, that is, for the reaccumulation of its energy stores, oxygen is required. The chemical changes involved in the entire contractile process are thus divided into two phases, the anaerobic or contraction phase and the aerobic or oxidative or recovery phase. The muscle when it contracts runs up an oxygen debt which pays when the contraction is over.

Chemical Changes :

The different types of chemical changes that take place during muscular contraction are the following: (1) Changes undergone by Adenosine-tri-phosphoric acid. (2) Changes undergone by Phosphagen or Creatine phosphate. (3) Changes undergone by Muscle Glycogen. (4) Changes undergone by Pyruvic acid and Lactic acid. (5) Changes undergone by Energy liberation.

I. Changes undergone by Adenosine-tri-phosphoric acid (A. T. P) : (a) *During Breakdown* **:** It takes place in anærobic condition. A. T. P. breaks down into A. D. P. and 2-high energy phosphate bond with the help of an enzyme, Adenosine-tri-phosphatase. Then A. D. P. breaks down into Adenylic acid and one low energy phosphate bond. This adenylic acid breaks down into adenine and d-ribose.

(b) *During Synthesis* **:** It takes place in aerobic condition i.e. in presence of O_2. Creatine phosphate combines with glycogen and forms phosphoric acid. The phosphoric acid combines with A.D.P. (Adenosine-di-phosphate) and forms A. T. P. with the help of an enzyme phosphorylase and co-enzyme adenosine tri-phosphatase.

II. **Changes undergone by Creatine Phosphate or Phosphagen :** In 1927, *Eggleton* and *Eggleton* obtained from muscles an organic compound of phosphoric acid. The creatine phosphate store is a constant supplier of A. T. P. During contraction, this compound breaks dnwn and liberates phosphoric acid which in the absence of oxygen, accumulates in the muscle. The Eggleton therefore calls it as phosphagen.

(a) *During Breakdown* : Creatine phosphate breaks down into creatine and phosphoric acid.

(b) *During Synthesis* : Creatine and phosphoric acid during synthesis form creatine phosphate.

III. **Changes undergone by Muscle Glycogen :** It takes place in anærobic state. The muscle glycogen breaks down into pyruvic acid and lactic acid during muscular contraction. There are very many researches have to wide acceptance of the most modern theory now known as "*Embden-Meyerhoff-Parnas*" (*E. M. P.*) pathway which offers a credible explanation by which glycogen molecules are converted into lactic acid. The breakdown of muscle glycogen during muscular contraction involves a series of reactions which may be summarised as : Muscle glycogen breaks down into glucose—1—phosphate with the help of an enzyme phosphorylase and liberates phosphoric acid. The glucose—1—phosphate breaks down into glucose—6—phosphate and fructose—6—phosphate by the activation of phospho-glucomutase and phosphohexose isomerase respectively. The fructose—6—phosphate breaks down into 3—phosphoglyceraldehyde and 2-phosphoenol pyruvic acid by the action of aldolase and enolase respectively. The phosphoenol pyruvic acid breaks down into pyruvic acid by transphosphorylase and lastly to Lactic acid by lactic dehydrogenase.

IV. **Changes undergone by Pyruvic acid and Lactic acid :** The oxidative degradation of pyruvic acid molecule takes place in several steps to CO_2 and H_2O after passing through a series of changes converting its successively into 6—5—4 carbon acids. This cyclic series is known as "*Kreb's Citric Acid Cycle*". It is probable that the greater part of pyruvic acid oxidise first and undergoes oxidative de-carboxylation to acetic acid which is then oxidised to CO_2 and H_2O through tri-carboxylic acid cycle. The cyclic series of glycolytic TCA pathway is summarised as : Pyruvic acid combines with oxalo-acetic acid forms citric acid by the activation of Acetyl co-enzyme A. Citric acid breaks down into α-Ketoglutaric acid and then succinic acid with the help of oxalo-succinic acid and Fumaric acid converts into Malic acid by the activation of succinic dehydrogenase and fumerse respectively. This Malic acid converts into oxalo-acetic-acid again by the action of malic dehydrogenase and in this way TCA cycle is going on.

V. **Changes undergone by Energy Liberation :** The actomyosin fibrils undergo actomyosin complex formation in presence of A.T.P.

which produces immediate contraction of muscle. During contraction of a muscle A. T P. releases which is bound with myosin and some energy is comming out with release of A. D. P. This A. D. P. is firmly bound with myosin portion of the atomyosin molecule. The energy for contraction would come from stored energy in actin and myosin molecules and not from A.T.P. During the process of contraction a large amount of water is released from actin and myosin molecule which is bound with them in a colloidal state and causes actual mechanical shortening of the fibrils. This shortening produces shrinkage that might occurs specially along the longitudinal axis. In other words, this shortenings reaction is due to dehydration of actin and myosin molecules will cause the bending of the actomyosin complex that satisfies the over all shortening of the muscle fibrils.

Q. 17. Describe the Electrical Changes during muscular contraction.

When the muscle contracts, there will be electrical changes in the muscle and these electrical changes are known as "Action Petential change". The electrical changes can be recorded with the help of Capillary electrometer, Einthoven's string galvanometer or Cathoderay oscillograph. In normal condition, the muscle fibres remain in a state of polarisation. When it is stimulated, it becomes depolarised and atonce current flows from +ve to –ve side in the outer circuit and in the opposite side direction through the muscle fibres. When a muscle is at rest, all the parts of the muscle are in the same electrical condition. But when it contracts, the contracting part becomes more negative at first in contrast with the parts of the muscle at rest and a wave of contraction passes along the muscle to the other end. The whole electrical response is completed long before the visible contraction is over. It occurs chiefly during the early stage of the development of tension during the latent period.

Electrical Changes : The various types of electrical changes that take place during muscular contraction are summarised as follows :

(a) **Polarisation :** The muscle is considered to be charged positively and negatively at its outer and inner surface respectively of its sheath which consist of two layers and they are all equipotential condition which is known as *Polarisation*. It was first Galvani who detected that electrical potential in all the tissues like muscle without the matallic electrode contractions. It has been definitely established by the earlier neurologists that every cell of the tissue in outer side is positively charged and the inner side is negatively charged and they are equipolarised and the value is zero in the resting condition of the muscle.

(b) **Current of Injury or Demarcation Current :** Muscle membrane is polarised—the other side is positively charged and the inner side is negatively charged. If a muscle is injured the injured surface becomes electronegative to the uninjured part.

Currents travel in the muscle from the injured to the uninjured part which is known as the *Current of injury or Demarcation current* whereas outside the muscle the current travels in the reverse direction. The contracting postion of a muscle also becomes negative to the rest.

(c) **Diphasic Variation :** When two points on the uninjured surface of muscle are connected to the galvanometer and if a single stimulus produces a wave of contraction, the contracting portion becomes of higher electrical potential and becomes negative to the rest of the muscle and as the waves travels along the galvanometer will exhibit two opposite variations with a neutral spot in the middle, known as *Diphasic Variation.*

(d) **Monophasic Variation :** When one of the two electrodes is placed on an injured surface, the current of action approaches the injured surface and becomes neutralised by the current of injury, thus exhibiting a condition called *Monophasic Variation.*

(e) **Secondary Contraction :** A contraction may be transmitted from the muscle to another by stimulating muscle over which is placed the nerve of another muscle, the impulse may secondarily be transmitted even from a tetanised muscle or from a contracting frog's heart.

(f) **All or None Law :** When the motor nerve to a muscle is stimulated under constant conditions, there is no response if the stimulus is below threshold strength. On the other hand, it contracts to its maximum. If the stimulus is adequate and even a greater stimulus fails to elicit a further increase in the response.

Q. 18. Describe the Thermal Changes during muscular contraction.

Daily day life experiment shows that there is increase of body temperature especially in the muscular region with the muscular activity and the degree of increase depending upon the degree of activity which can be easily recorded by putting thermometer and the functional place is a joint where the two groups of muscle meet together. By using highly sensitive Fenn's microcalorimeter, it is found that heat is evolved in two stages, the *initial heat* and *the delayed heat.* The initial heat is slightly aerobic and mostly anaerobic. The delayed heat is mostly aerobic.

I. **Initial Heat :** It is purely anaerobic in nature. It takes place both during contraction and relaxation on a muscle. It is the sum total heat (i.e., 25,000 Cals) produced by exothermic and endothermic reactions.

(a) *Exothermic Reactions* **:** The initial heat is produced by the breakdown process which are : (1) A. T. P. breaks down into A.D.P. and Phosphoric acid. (2) Phosphagen breaks down into creatine and phosphoric acid. (3) Muscle glycogen breaks down into pyruvic acid and lactic acid. (4) The lactic acid is partly converted into lactate.

(b) *Endothermic Reactions* : The initial heat is produced by the synthetic changes which are : A. D. P. combines with phosphoric acid and forms A. T. P. (2) Creatine combines with phosphoric acid and forms phosphagen or creatine phosphate.

II. **Delayed Heat** : It is known as "Recovery Heat" because this delayed heat is produced during recovery stage of the muscle. It is mostly aerobic and slightly anaerobic.

(*a*) *Aerobic Delayed Heat* : It is the sum total heat produced by exothermic and endothermic reactions. (1) The exothermic reaction is produced by the oxidation of lactate and produced 32,000 Cals of heat. (2) The endothermic reactions are produced by the resynthesis of the greater part of creatine phosphate and the resynthesis of glycogen.

(b) *Anaerobic Delayed Heat* : It is produced by the breakdown of creatine phosphate and 11,000 Cals. of heat are liberated.

According to *A. V. Hill*, the production of heat in a singly twitch of a frog's muscle may be divided into three stages : (1) *The heat of activation* : It occurs immediately after stimulation and diminishes while the contraction proceeds. The heat production occurs about ten milliseconds after stimulation (2) *The heat of shortening* : It depends upon the amount of shortening—ax, where x denotes the amount of shortening and a is the constant. (3) *Recovery heat* : In this stage, the production of heat becomes slow in the presence of oxygen. The heat of shortening begins later. There is no heat of relaxation.

Q. 19. Describe the different changes during Muscular Exercise.

The muscle forms the main bulk of the body which is covered by sarcolemma. The skeletal muscle fibres consist of a series of striated fibrils or sarcostyles between which is found undifferentiated sarcoplasm The fibrils show light and dark bands alternately. During exercise the metabolic needs of the body is increased and oxygen is required which is adequately met mith from the adjustment of various systems. Exercise produces anoxia, CO_2 excess, increased hydrogen-ion concentration, excess metabolism, excitement, adrenaline secretion, rise of temperature and so on. These factors alter the activities of the different system by their cantral and peripheral action and regulate the functional level according to the needs of the body. There are different changes that take place during muscular cantraction are summarised below :

I. **Blood Changes** : (1) The force and velocity of blood increases. (2) The cellular elements of the blood will increase in their count due to the contraction of the spleen. (3) Venous blood returns with less amount of exygen. (4) Acidosis will occur due to excess carbon dioxide and in severe exercise, lactic acid is entered in the blood.

II. Circulatory Changes :

(a) **General Changes :** (1) The venous return is increased due to vigorous muscular contractions by the valves in the veins, increased depth and frequency of respiration and increased capillary and venous pressure. (2) The increased venous return provides the blood flow for a greatly increased cardiac outpout. (3) The heart rate increased due to impulses coming from the higher centres, set up auricular reflex, rise of CO_2 tension and O_2 lack and rise of temperature. (4) The general vaso-constriction is caused due to the direct action of O_2 lack, CO_2 excess, reflexes coming from sino-aortic regions and reflexes coming from active muscles. (5) The contraction of the spleen pumps out the stored blood into the general circulation. (6) The blood pressure increases, the observed rise of blood pressure is relatively small which shows that the total peripheral resistance in exercise is decreased by the dilatation of the muscle vessels for outweighs the constriction of splanchnic area and skin.

(b) **Local Changes :** (1) The arterioles, capillaries and venules are dilated. If the contractions of the muscle are replaced several times, it is found that contraction temporarily dimihishes the muscle volume to some extent, but the volume gradually increases during each interval of relaxation, (2) Most of the capillaries will remain collapsed at rest and after certain period, it opens up. This is done by CO_2 lack, excess CO_2, increased H-ion concentration, metabolites, histamine, increased temperature, adrenaline action, slowing of blood flow, increased vascularity, more extensive reduction of oxyhaemoglobin.

III. Respiratory Changes :

(a) *Pulmonary Ventilation* : Respiration increases both in rate and depth only to supply more oxygen to individual alveolus and to eliminate CO_2 for maintaining blood reaction. If the exercise is moderate, the pulmonary ventilation is increased to a degree which is proportional to the severity of the exercise. The increased breathing is brought about by appropriate stimulation of the respiratory centre : (1) By impulses from the higher centres produced by the emotional tension before the exercise begins. (2) By the raised CO_2 tension of the blood. (3) By any rise of body temperature that may occur. After the exercise is over the breathing rapidly settles down to the resting level as the excess of CO_2 is eliminated. But if the exercise is severe, breathing remains much above the resting level for prolonged period even after the exercise is over.

(b) *Increased Oxygen Consumption* : The increased pulmonary ventilation supplies this excess O_2 when the reduction of O_2 supply in the lungs takes place. The output of CO_2 rises which is propotional to exercise.

(c) *Respiratory Quotient (R. Q.)*: It varies according to the degree of exercise: (1) In moderate exercise, the R. Q. varies from 0·85 to 0·89 i.e. more or less same as in the rest. (2) In prolonged exercise, R. Q. falls to 0·7 (3) In severe exercise, the R. Q may increase upto 1·5 to 2 due to much greater H-ion concentration than in moderate exercise.

IV. Renal Changes: (1) Urine volume will reduce due to vaso-constriction of the renal blood vessels. (2) The urine becomes acidic at first and later it becomes alkaline due to excess washing out of CO_2.

V. Skin Changes: (1) Vaso-constrictions of the cutaneous blood vessels causes more and more loss of heat. (2) There will be vaso-dilatation that leads to sweating.

VI. Fatigue: (1) In severe exercise, the degree of fatigue becomes earlier. (2) The fatigue occurs due to the effect of anoxia and increased H-ion concentration upon the central nervous system.

VII. Digestive Changes: Severe exercise inhibits both the motor and secretory functions of stomach. The moderate exercise inhibits gastric secretion and motility of the stomach but the lighter exercise as in walking, helps in gastric juice secretion.

VIII. Endocrine Changes: During exercise, the utilisation of growth hormone is increased for quick mobilisation of depot fat. In physical exercise, ADH secretion is increased which actually combats against dehydration during exercise. In moderate exercise, there is no alteration in the functions of thyroid hormone.

The chief points of differences between moderate and severe exercise are given in a tabular form below:

Different Changes	Moderate Exercise	Severe Exercise
I. Cardiovascular: (a) General.	Increased heart rate, venous return, cardiac output and blood pressure.	Same but more in amount.
(b) Local.	Dilatation of blood vessel and increased vascularity.	Same but more in amount.
II. Respiration: (a) Pulmonary Ventilation.	Increases but comes to normal when exercise stops.	Remains high for a long time.

Dfferent Changes	Moderate Exercise	Severe Exercise
(b) R. Q.	Almost normal i.e. 0·85 to 0·90.	Becomes high i.e. 1·5 to 2·0 but falls into 0·5.
III. **Blood :**		
(a) Cell count.	It rises.	It rises.
(b) Lactate.	Normal i.e. 10 to 20 mgm %.	Raised i.e. 100 to 200 mgm %.
(c) Acidosis.	Present.	More.
(d) Alkali reserve.	Reduced.	More reduced,
IV. **Digestion :**	Inhibits gastric secretion and motility of the stomach.	Inhibits motor and secretory functions of the stomach.
V. **Endocrine :**	No alteration in the functions of thyroid hormone.	Utilisation of growth hormone and increased secretion of ADH.
VI. **Renal :**		
(a) Volume.	Less.	Less.
(b) Reaction.	Acid.	Acid, later alkaline.
VII. **Skin :**		
(a) Vessels.	Constriction but later dilatation.	Same.
(b) Sweat.	Reduced but later increases.	Same.
VIII. **Fatigue :**	Delayed.	Early.

Q. 20. Write Short Notes on : Sarcolemma, Myelin Sheath, Nissl granules, Nissl Degeneration. Wallerian Degeneration, Motor End plate Adenosine Tri-phosphate, Spike potential, Chronaxie, Rheobase, Neurone, Neuroglia and Synapse.

(a) **Sarcolemma :** Each part of a muscle contains contractile *myofibrils* which are usually arranged in bundles. *Sarcolemma* is a thin delicate covering which covers each myofibrils. It protects the muscle fibres from any sorts of injury.

(b) **Myelin or Medullary Sheath :** It is a highly refractile, whitish, double contour sheath closely invest the axis cylinder process. The point where the myelin sheath is deficient, is known as Nodes of Ranvier. **Composition :** The important constituents of myelin sheath are cephalin, lecithin, phosphoric acid, cholesterol and cerebroside or spingomyelin. The mitochondria are disposed radially in the myelin sheath. A reticular appearance is also seen in the myelin sheath. **Functions :** (1) The myelin sheath closely covers the axis cylinder process and is responsible to give the white colour to a nerve. (2) It is believed to act as an insulator or non-conducting material, ensuring isolated conduction of a nerve ismpulse within a nerve fibre. (3) It is possibly concerned with the presence of the fatty materials, (4) It prevents decepassion of nerve fibres i.e. loss of current of the impulse when it passes from different segment of the nerve fibres. (5) The speed of conduction depends upon the thickness, thinness or absence of medullary sheath. When myelin sheath is thinner, the speed will be slower, when it is thicker, the speed will be faster.

(c) **Nissl Granules or Tigroid Substance :** These are angular or spindle-shaped bodies present in the cytoplasm of nerve cells, staining deeply with basic dyes, the methylene blue. Their number and size vary with the physiological condition of the nerve cell. The Nissl granules are seen to disintegrate and disappear in fatigue, section of the axon, action of certain nerve-poisons and circulatory disturbances. **Occurrence :** They are found in the dendrites, may be scanty in some nerve cells but they are absent in the axon hillock, in the axon and some small cells of the grey matter of the brain. **Composition :** Chemically, the Nissl granules consist mainly of nucleoproteins and contains organically combined iron. The nucleus is large, shows a well marked chromatin network and nuclei. **Functions** *:* (1) The Nissl granules act as a store-house of nutritive material of the cell and after lesions or injuries of the neurone, chromatolysis takes place with the disappearance of Nissl granules. (2) It is believed that it supplies nutrition to the cell body during activity.

(d) **Nissl Degeneration :** It is a process of degeneration of the Nissl granules caused due to the section of the medullated nerve fibre. There are certain changes that take place,. are the following : (1) *Changes in that portion of the nerve* still attached to the cell, upto the first node of Ranvier : (i) Neurilemma sheath thickens and nuclei multiply. (ii) The medullary sheath breaks into fatty oily myelin droplets. (iii) The neurilemmal tube ultimately enclosing a mass of granular neuroplasm containing many nuclei, is left. (2) *Changes in the Nerve cell* **:** (i) The Nissl granules disintegrate within 24 to 48 hours after section and reach its zenith in about 18 days. (ii) The cytoplasm becomes swollen. (iii) The nucleus assumes an eccentric position. (iv) The dendrons may disappear. (v) The disintegrated chromatin substance disappears and the cell body and the nucleus become shrunken in volume.

(e) **Wallerian Degeneration** *:* When a nerve fibre is cut transversely, there are acute changes known as traumatic degeneration but the peripheral portion also shows simultaneously along its whole length produces secondary degeneration. The foregoing changes were first observed by Waller and are known as *Wallerian degeneration.* **Occurrence :** The process of degeneration sets in within 24 hours and on the third day, the fibre ceases to conduct impulses. The degeneration is completed in three weeks. **Causes :** The causes of degeneration are : (1) Due to the cutting of the nerve fibre within 24 hours. (2) Due to the exhaustion and intoxication such as in extreme fatigue condition. (3) Decreased blood supply. (4) In hyperpyrexia i.e. brief exposure to 109° F. causes coagulation of the substance (5) Action of certain nerve poisons. **Changes of Degeneration :** (1) The neurilemma cells rapidly proliferate and the neurilemma sheath thickens, nuclei multipy and the surrounding protoplasm increases in amount. (2) The medullary sheath disintegrates into irregular myelin droplets and undergoes chemical changes liberating highly unsaturated fatty acid. (3) The neurofibrils become swollen and fused and shortly afterwards, the axis-cylinder process breaks up into irregular short lengths. (4) The proliferated neurilemma cells with histocytes of the surrounding connective tissue digest and absorb the remnants of axis cylinder and myelin sheath. (5) The neurilemmal tube consisting of modified neurilemmal cells encloses a mass of granular protoplasm containing many nuclei is left. There is increase of water and diminution of phosphorus within the tube.

(f) **Motor End Plate :** It is a plate like structure formed by the effector organ and the efferent nerve fibres. **Formation** : The nerve terminals of the efferent motor nerve spread through the muscle fibre. **Structure :** The motor end plate is made up of undifferentiated tissue which contains acetyl choline and adrenaline. The expanded nerve endings or *sole feet* do not end within the sarcoplasm but a gap is present in between which is known as *synaptic cleft.* The sole feet contains mitochondria, numerous vesicles, smaller granular elements and endoplasmic reticulum. **Functions :** The motor end plate receives motor impulses and acts as an effector organ. It helps in the mechanism of the neuromuscular transmission.

(g) **Adenosine-Tri-phosphate (A.T.P.)** : During muscular contraction after application of any types of stimulus, Adenosine-Tri-phosphate (A.T.P.) is liberated from the muscle. The changes that take place during breakdown and synthesis of Adenosine-Tri-phosphate are as follows : (1) **During Breakdown .** It takes place in anaerobic condition. A.T.P. breaks down into A.D.P. and 2-high energy phosphate bond with the help of an enzyme known as Adenosine-triphosphatase. The A M.P. and one low energy phosphate bond formed with the help of an enzyme known as Adenosine-diphosphatase. The A.M.P. breaks down into Adenylic acid with the help of an enzyme known as Adenosine-mono-phosphatase This adenylic acid breaks down into adenine and d-ribose. (2) **During Synthesis :** It takes place in aerobic condition i.e. in presence of oxygen. Creatine phosphate combines with glycogen and forms phosphoric acid. The phosphoric acid combines with A.M.P. (Adenosine-mono-phosphate) and forms A.D.P. (Adenosine-di-phosphate). The A.D.P. combines with phosphoric acid and forms A.T.P. with the help of an enzyme known as phosphorylase and co-enzyme, adenosine tri-phosphatase.

(h) **Spike Potential:** When an injured nerve is stimulated the action currents flowing, as detected by the initial deflection of the needle, are extinguished when they reach the site of injury with cessation of the needle deflection. This is known as *Spike potential* or *Monophasic variation.*

(i) **Chronaxie:** It is the minimum time required for excitation of a tissue by an electric current which has double the threshold intensity of a steady current. It is the physiological unit of time and is expressed in thousands of a second or millisecond. The chronaxie in millisecond of frog's skeletal muscles is 0·4. A **long chronaxie** of a muscle is found to increase: (1) After degeneration of its motor nerve. (2) On development of fatigue and (3) When poisoned by curare or sparteine. A **short chronaxie** is found in a nerve when it has: (1) A short refractory period. (2) A rapid rate of propagation of impulse. (3) Large size of the fibres. (4) A brief time of action. (5) Its myelin sheath swollen by reagents and (6) A stimulation by strychnine.

(j) **Rheobase:** It is the voltage in the weakest constant current which stimulates activity in a required time during which it acts on tissue.

(k) **Neurone:** A neurone is the structural and the functional unit of the central nervous system consisting of cell body and its processes such as a single large process known as axon or axis cylinder and the smaller numerous processes known as dendron or dendrites. **Structure:** A neurone is made up of a nerve cell body and the processes. The *nerve cell body* contains a central single nucleus with nucleolus, mitochondria, golgi apparatus, pigments, Nissl granules, neurofibrils etc. The *nerve processes* consists of a single process known as Axon or Neuraxon or Axis cylinder and numerous smaller processes known as Dendrons or Dendrites or Protoplasmic processes. **Functions:** (1) *Functions of a Nerve cell body:* (i) The nucleus with nucleolus maintains the vitality of nerve cells. (ii) The neuro-fibrils are believed to be the actual conductors of nerve impulses. (iii) The Nissl granules are intemately concerned in the metabolic activity of the cell and are closely connected with the nutritional condition of the neurone. (2) *Functions of Nerve processes:* (i) The axon carries nerve impulses away from the cell body. (ii) The dendron carries nerve impulses towards the cell body and behaves as a sensory fibre.

(l) **Neuroglia:** The neuroglia forms the supporting component of the nervous tissue which is mainly developed from ectoderm and partly developed from mesoderm. **Types:** There are four types of neuroglial cells which are known as Astrocytes, Oligodendrocytes, Ependymal cells and Microglia or Mesoglia. The first three types of cells are ectodermal in origin but the last one is mesodermal in origin. **Functions:** (1) The neuroglia forms the supporting component of the nervous tissue from where most of the neurone starts and go in different directions for their activity (2) The microglia becomes amoeboid and phagocytic in pathalogical conditions and wonder in the meninges and blood vessels in the central nervous system. (3) The astrocytes serve as a regulator of the ionic environment of the neurones and thought to prepare the blood-brain barrier. (4) The oligodendroglia helps in the formation of myelin sheath in the central nervous system.

(m) **Synapse :** The synapse is a neuro-neural junction when one neurone ends and arborises with the nerve cell by its processes and other begins from there. It is the basic functioning unit of the central nervous system. **Formations :** The synapse may be formed by the following ways : (1) Between the axon of one neurone and the dendrites of the other. (2) Each terminal nerve fibril of the axon ends in a small knob-like button and may embrace the membrane of the dendrites and as network around them. (3) A number of neurones may communicate through a common synapse. **Properties :** The synapse possesses a number of properties which are : One way transmission of implse, Synaptic delay, Synaptic block, Seat of fatigue, Facilitation, Distributing action, Convergence, Divergence and Commutator action. **Functions :** A synapse performs the following functions : (1) It relays nerve impulses and transmits the impulses in all directions. (2) It selects which impulses are to be allowed to pass and which ones are to be blocked. (3) It sometimes amplifies the afferent nerve impulses. (4) It sometimes decreases the number of transmitted impulses.

NORMAL LABORATORY DATA OF CLINICAL INTEREST

I. URINE :

Daily Output = 800 to 1500 ml. per. 24 hours,
Specific Gravity = 1010 to 1024.
Calcium = 0·1 to 0·7 g. per 24 hours.
Chlorides at NaCl = 10 to 15 g. per 24 hours.
Total Nitrogen = 12 to 18 g. per 24 hours.
Urea = 20 to 35 g. per 24 hours.
Urobilinogen = 0 to 4 mg. per 100 ml.

II. BLOOD :

A. Haematology :

Total Erythrocytes per cu. mm. (T. C.)
  (1) In Male = 4·73 to 5·49 millions.
  (2) In Female = 4·14 to 4·79 millions.

Haemoglobin per 100 ml.
  (1) In Male = 14·41 to 16·32 g.
  (2) In Female = 11·89 to 14·10 g.

Total Leucocyte per cu. mm .(T.C.)
  (1) In Male = 5000 to 8000
  (2) In Female = 4500 to 7000

Differential Count (D.C.) :
  (1) Neutrophils = 60 to 70%
  (2) Eosinophil = 1 to 4%
  (3) Basophil = 0 to 1%
  (4) Lymphocytes = 20 to 30%
  (5) Monocytes = 2 to 6%

Packed Erythrocyte Volume (C.V.)
  (1) In Male = 38·75 to 44·70 per 100 ml.
  (2) In Female = 33·22 to 39·32 per 100 ml.

Mean Corpuscular Volume (M.C.V) = 78 to 94 cubic microns.

Mean Corpuscular Haemoglobin (M.C.H) = 24 to 38 micromicrograms.

Mean Corpuscular Haemoglobin concentration (M.C.H.C) = 30 to 35%

Colour Index (C.I.)
  (1) In Male = 0·95 to 1·06%
  (2) In Female = 0·94 to 1·07%

Volume Index (V.I.)
  (1) In Male = 0·93 to 1·07%
  (2) In Female = 0·94 to 1·07%

Saturation Index : (S.I.)
  (1) In Male = 0·95 to 1·06%
  (2) In Female = 0·93 to 1·07%

Platelets = 2 to 5 lacs per cu. mm.
Reticulocytes = 0 to 0·8%

B. Chemistry ;

Constituents — *Normal Range per 100 ml,*

Bilirubin = 0·1 to 0·3 mg.
Calcium = 7 to 11 mg.
Blood Chloride = 450 to 500 mg.
Plasma Chloride = 470 to 620 mg.
Serum Chloride = 350 to 390 mg.
Blood Cholesterol = 150 to 200 mg.
Serum Cholesterol = 150 to 200 mg.
Creatinine = 1 to 2 mg.
Glucose (fasting) = 80 to 120 mg.
Icteric Index = 2 to 6 units.
Lipase = 0·5 to 1 units
Non-protein Nitrogen = 20 to 40 mg.
Acid phosphatase = 0 to 1·2 units Bodansky.
Alkaline phosphatase = 2 to 9 units Bodansky.
Inorganic phsphorous = 3 to 5 mg.
Total serum phsphorous = 35 to 45 mg.
Blood Potassium = 150 to 250 mg.
Serum Potassium = 16 to 22 mg.
Total Protein = 6 to 8 g.
Albumin = 4 to 5 g.
Globulin = 2 to 2·5 g.
Fibrinogen = 200 to 400 mg.
Blood Sodium = 170 to 295 mg.
Serum Sodium = 310 to 350 mg.
Urea = 15 to 30 mg.
Urea Nitrogen = 10 to 15 mg,
Uric Acid = 2 to 4 mg.
Water Content = 75 to 81%

A. Haematology :

Fragility of the Erythrocytes : (1) Maximum resistance = 0·30 to 0·34% NaCl. (2) Minimum resistance = 0·40 to 0·46% NaCl.
E.S.R (Westergren) in 1 hour. (1) In Male = 2 to 6 minutes. (2) In Female = 2 to 8 minutes.
Bleeding Time = 1 to 3 minutes. Coagulation Time = 6 to 10 minutes.
Prothrombin Time (Quick) = 12 to 14 seconds.
Blood Volume : (1) Per kg. body weight = 70 to 100 ml. (2) Per sq. meter of body surface = 2800 to 3800 ml.

III. GASTRIC ANALYSIS (Oat Meal) :

Fasting Volume = 10 to 100 ml.
Free Acidity = 20 to 50 ml. N/10 HCl (NaOH) per 100 ml. of gastric contents.
Total Acidity = 50 to 100 ml. N/10 HCl (NaOH) per 100 ml. of gastric contents.

IV. CEREBRO-SPINAL FLUID :

Pressure = 100 to 200 mm. of water.
Proteins = 25 to 45 mg. per 100 ml.
Glucose = 45 to 75 mg. per 100 ml.
Chloride as NaCl = 700 to 750 mg. per 100 ml.
Cells = upto 5 per cu. mm. all lymphocytes.

V, FAECES : (of dried faeces)

Total Fat = up to 25%
Split Fat = up to 20%
Neutral Fat = up to 5%

VI. PH OF BODY FLUIDS :

Gastric Juice (maximum) = 1·8
Pancreatic Juice = 8·3
Urine = 6·0
Blood = 7·3 to 7·35
Human Milk = 6·8

VII. LIVER FUNCTION TESTS :

(1) *Bilirubin Tolerance* : After intravenous injection of bilirubin 1 mg. per kg body weight nearly all bilirubin is excreted in 4 hours and blood does not show a retention over 6%.

(2) *Galactose Tolerance* : Excretion of not more than 3 g. of galactose in the urine in 5 hours after injection of 50 g. of galactose.

(3) *Prothrombin Test* : Increase of 15% or more in the prothrombin concentration in the blood in 24 to 28 hours after injection of synthetic vitamin k.

(4) *Thymol Turbidity Test* : 4 units or less.

VIII. RENAL FUNCTION TESTS :

(1) *Phenosulfonephthalein* : Intramuscular injection of 6 mg. of dye, 40 to 60% in the urine in 1 hour and 60 to 85% in 2 hours.

(2) *Specific gravity* : Fluid is witheld for 24 hours. The urine passed during the time should show a specific gravity of 1026 or over.

(3) *Urea Clearance* : 40 ml. or more of blood cleared per minute, 75 to 120% of average normal.

(4) *Urea Cancentration* : After administration of 15 g. of urea the first one hour sample contains at least 1·5% urea and the second hour sample at least 2%.

CHAPTER
ONE

ENDOCRINOLOGY

Introduction : The subject Endocrinology or Endocrine system constitutes a number of ductless glands which manufacture certain chemical substances known as *hormones*. They are released directly in the blood and carried everywhere by the blood stream but they act only on certain specific organs and life processes of the body. The endocrine system in an animal controls the following activities, such as : (1) The time, order and rate of growth and development of different organs of the body, (2) Process of metamorphosis in amphibians, (3) Adaptive colouration of certain animals in larval and adult condition, (4) Development of primary sexual organs and secondary sexual characters, (5) Different phases of behaviour, specially emotions that contribute a lot to the psychic or mental life and to the determination of personality throughout the whole life. The nervous system serves the endocrine function and plays a major role in homoeostatis. The two systems are integrated, interdependent and possess a reciprocal relationship at the hypothalamic level. The hypothalamus liberates several hormones that control major hormonal activities of the body through pituitary gland representing neuroendocrine system. Disorders in the balance of endocrine activities produce several pathological conditions of the body and loss of the glands of internal secretions may prove fatal in daily day life in the human being.

There are two types of glands in the body known as *Exocrine* and *Endocrine* glands. The *exocrine glands* or glands of external secretions are those which discharge their secretions through ducts on the surface of the body and serves mainly the digestion, absorption, metabolism and a least endocrine functions. The exocrine glands of the body are the salivary glands and liver, with ducts to the digestive tract and the mammary glands and sweat glands, with ducts opening on the body surface. The *endocrine glands* or ductless glands or glands of internal secretions are those which discharge their secretions (hormones) into the blood stream that is carried to the various parts of the body. The internal secretions known as hormones which exercise a profound regulatory control over many bodily functions, stimulating or inhibiting the development, growth and activities of various tissues and influencing the behaviour of the individual. The endocrine glands include the pituitary, thyroid, parathyroids, islets of Langerhans, adrenals and gonads and doubtfully, the pineal body or epiphysis and thymus.

The endocrine glands of the body are of various types which have been classified into :

I. **According to Functions** : The endocrine glands of the human body are classified into :

(a) *Glands concerned with definite endocrine functions* : These include Pituitary gland (Anterior and Posterior lobe), Thyroid, Parathyroids, Adrenal or Supra-renals (Cortex and Medulla), Islets of Langerhans, Testes, Ovary, Placenta (during pregnancy).

(b) *Glands concerned with probable endocrine functions* : These include Thymus and Pineal body (Epiphysis).

(c) *Glands concerned with digestive functions* : These include Salivary (Bradykinin or Kallidin), Gastric (Gastrine, Enterogastrone, Urogastrone), Pancreatic (Pancreozymin, Secretin), Hepatic (Cholecystokinin, Bile) and Intestinal (Duocrinin, Villikrinin, Enterokrinin), etc.

· · II. **According to Locations in the Body** : The endocrine glands have been grouped according to location or situation for the sake of convenience in study.

(a) *Cranial Endocrine glands* : These types of endocrine glands lie with the head region. They are Pituitary gland or Hypophysis and the Pineal body or Epiphysis.

(b) *Pharyngeal Endocrine glands* : These types of endocrine glands are situated in the pharyngeal or neck region, They are Thyroid, Parathyriods and Thymus.

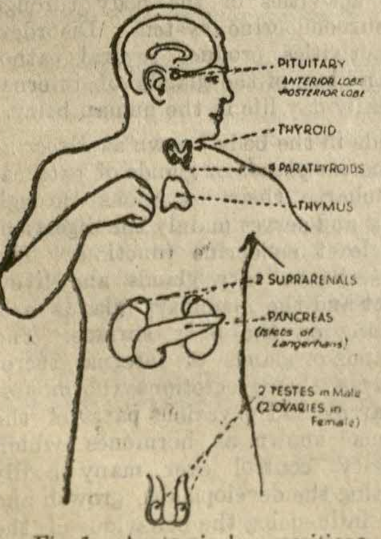


Fig. 1. Anatomical positions of different Endocrine Glands in the human body.

(c) *Abdominal Endocrine glands* : These types of endocrine glands are situated in the abdominal region. They are Islets of Langerhans, Adrenals or Supra-renals, Ovary, Testes (in foetal life), Intestinal glands etc.

III. **According to Number and Mode of Secretions**: The endocrine glands can be classified according to number and mode of action into unilateral, bilateral and mixed.

(a) *Unilateral glands* : These are single glands situated in the body. They are Pituitary, Thymus, Islets of Langerhans, etc.

(b) *Bilateral glands* : These are paired glands situated one on each side of the body. They are Thyroid, Parathyroids, Adrenals or Supra-renals, Testes, Ovary etc.

(c) *Mixed type of glands* : These glands have got exocrine and endocrine secretions. They are Pancreas, Testes and Ovary.

Q. 1. "The Anterior Pituitary gland is the leader of endocrine orchestra"—Discuss the accuracy of the statement.

The anterior pituitary gland through trophic hormones controls the secretion of hormones from the different endocrine glands. The secretion of Thyroxine by the Thyroid gland is under the influence of Thyrotrophic hormone or T.S.H., the secretion of cortical hormones by the supra-renal cortex is under the influence of A.C.T.H. and the secretion of sex hormones from the gonads is under the influence of gonadotrophic hormones like F.S.H., L.H. or I.C.S.H. and Leuteotrophic hormone.

Proof of the Statement : The accuracy of the statement can be proved by different experimental methods as for example by the method of extirpation or removal of anterior pituitary gland, by the methods of stimulations i. e. injection of the extract of anterior pituitary gland to normal healthy individual and by clinical manifestations.

I. Methods of Removal : When the anterior pituitary gland is removed, there will be no secretion of trophic hormones and there will be atrophy of the different endocrine glands as for example the atrophy of thyroid, supra-renal cortex, gonads, etc. The removal of the gland will also prevent the secretion of the hormones from the different endocrine glands and there will be manifestations of hypoactivity of the different endocrine glands.

As there is on secretion of thyroxine there will be manifestations of hypothyroidism, no secretion of cortical hormones and there will be manifestations of *Addison's disease*, on secretion of the sex hormones and as a result no growth of accessory sex organs and no development of secondary sexual characters before puberty.

II. Methods of Stimulation : The injection of the extract of the anterior pituitary gland will cause more secretion of the hormones from the different endocrine glands and there will be manifestation of the hyperactivity of the different endocrine glands. (1) The injections of Thyrotrophic hormone will cause more secretion of Thyroxine and there will be manifestations of *Exophthalmic Goitre*. (2) The injection of adreno-corticotrophic hormone will produce hyperactivity of the supra-renal cortex causing manifestations of *Cushing Syndrome*. (3) The injection of gonadotrophic hormones before puberty will cause premature development of the accessory sex organs and early appearance of secondary sexual characters.

III. Clinical Manifestations : (1) Tumours of the alpha cells of the anterior pituitary gland before puberty will produce a condition called *Gigantism*. (2) Tumours of the basophil cells will cause increased liberation of A. C. T. H. which will produce the manifestations of *Cushing's Syndrome*.

From the above experimental evidences it can be difinitely proved that anterior pituitary gland is the leader of the endocrine orchestra.

Q. 2. Describe the structure and active principle of Anterior pituitary gland and discuss the interrelations with other endocrine glands.

The pituitary gland is the band master of endocrine orchestra because it not only controls the different types of endocrine glands but also maintains and regulates body growth, metabolism, lactation and also has an indirect influence over all other endocrine glands.

Situation : Pituitary gland is situated at the base of the brain. It has got a short stalk known as *infundibulum* or *neural stalk.* It is lodged within a bony compartment known as *sella turcica* of the sphenoid bone which is closed above by a membrane known as *diaphragma selle* that is pierced by the pituitary slalk.

Development : The anterior pituitary gland is developed from the Rathke's pouch or Adenohypophysis of pharyngeal ectoderm.

Anatomy : Pituitary, the small endocrine gland has 0·5 to 1 gm. in weight. Its average dimension becomes 10 m.m. (antero-posteriorly) × 13 m.m. (laterally) × 6 m.m. (dorso-ventrally). It is larger in females. It has got a short stalk known as infundibulum.

Histology : Histologically, anterior pituitary gland consists of two parts known as pars distalis or pars anterior and pars tuberalis.

(*a*) **Pars Distalis :** It consists of nests of cell separated by capillaries.

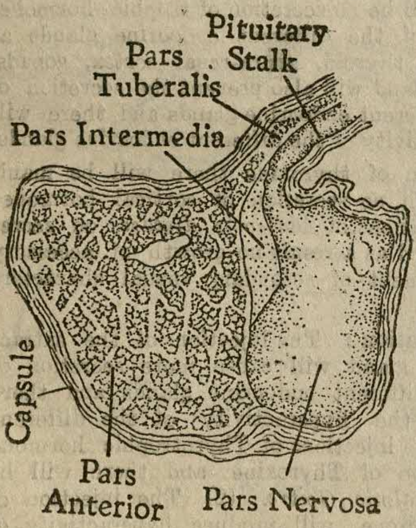


Fig. 2. Anatomical Structure of Pituitary Gland.

(1) **Chromophobe cells** (50%) : They take no or very little stain, have no granules and apparently do not secrete anything. It is smaller in structure with homogeneous cytoplasm. The globules or colloid material are often seen in the cells, which ultimately find their way into the third ventricle.

(2) **Chromophil cells** (50%) : They are filled up with

cytoplasmic granules which are stained both by acid and basic dyes. They are sub-divided according to the character of their granules into: (i) *Acidophil cells* or *Eosinophil cells* or *Oxyphil cells* or *α-cells* (35%): These cells are granular and take eosin or acid fuchsin stain. They constitute somatotrophic cells and lactotrophic cells. (ii) *Basophil cells* or *β-cells* (15%): These cells are also granular and take basic haematoxylin stain. They comprise thyrotrophic cells, gonadotrophic cells and corticotrophic cells.

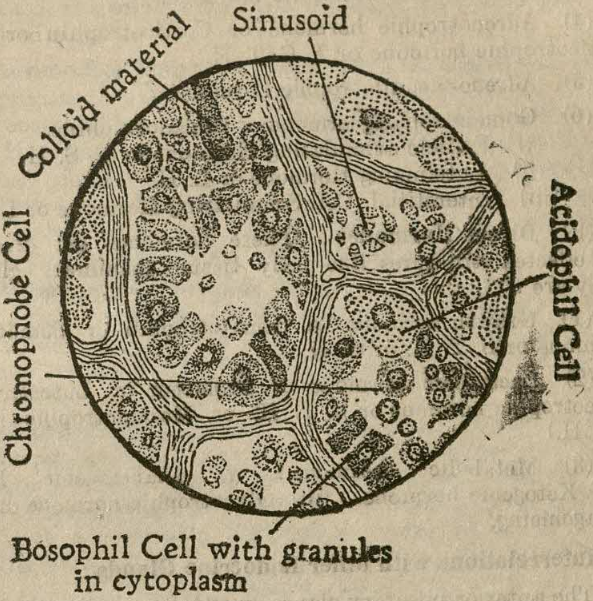


Fig. 3. Histological Structure of Pars Anterior of Anterior Pituitary Gland.

(3) **Intermediate cells**: These type of cells are granular and take both acid and basic stains.

(b) **Pars Tuberalis**: It contains trabeculae or certain solid cords of cells. These cells are non-granular and chromophobe in nature. It has got no function in man. It consists of numerous vesicles lined by basophil cells. The vesicles contain coagulated fluid and degenerated cellular elements.

Active Principle: The anterior pituitary gland produces several hormones, some of them are indirect and others are direct hormones.

(a) **Indirect Hormones**: These hormones are not directly act upon endocrine glands. They are:

(1) Thyrotrophic hormone or Thyroid stimulating hormone or T. S. H. or Thyrotrophin.

(2) Parathyrotrophic hormone or Parathyrophin or Parathyroid stimulating hormone or P. S. H. (?)

(3) Pancreo-medullotrophic hormone.

(4) Adrenotrophic hormone or Corticotrophin or Adrenocorticotrophic hormone or A. C. T. H.

(5) Adreno-medullotrophic hormone (?)

(6) Gonadotrophic hormone or Gonadotrophins.
  (i) Follicle Stimulating Hormone or F. S. H.
  (ii) Luteinizing Hormone or L. H.
  (iii) Interstitial Cell Stimulating Hormone or I. C. S. H.

(b) **Direct Hormones** : These hormones act directly on the effected structures like body tissue, mammary gland etc. They are :

(1) Growth hormone or Somatotrophin or Somatotrophic hormone or S. T. H. or G. H.

(2) Lactogenic hormone or Prolactin or Luteotrophin or Luteotrophic hormone or L. T. H. or Mammotrophic hormone (M. H.)

(3) Metabolic hormone : (i) Diabetogenic hormone. (ii) Ketogenic hormone. (iii) Glycotrophic hormone or Insulin antagonising.

Interrelations with other Endocrine Glands :

The anterior pituitary gland, directly or indirectly controls almost all the endocrine glands of the body and makes an interrelations with those glands.

(1) **Thyrotrophic Hormone** : This hormone regulates the growth and activity of the thyroid gland, controls the secretion of thyroxine from the thyroid gland and indirectly influences metabolism. Hyperactivity of anterior pituitary will cause increased secretion of thyroxine hormone from the thyroid gland producing *Exophthalmic goitre.* Removal of anterior pituitary will cause diminished secretion of thyrotrophic hormone causing *Myxoedema* and *Cretinism.* Now-a-days, it is believed that the thyrotrophic hormone acts as a proteolytic enzyme and helps in the splitting up of the thyroglobulin, a complex colloidal material, into thyroxine and globulin.

Blood iodine level controls the secretion of thyrotrophic hormone from the anterior pituitary. High iodine level will inhibit the secretion of thyrotrophic hormone from thyroid gland.

(2) **Parathyrophic Hormone** (?) : The anterior pituitary liberates Parathyrotrophic hormone. The parathormone regulates calcium and phopshorous metabolism and keep it in a normal level.

(3) **Pancreo-medullotrophic Hormone** : It is liberated from anterior pituitary gland which acts upon the pancreatic

medulla specially on the Islets of Langerhans and controls the secretion of Insulin from β-cells of Islets. This insulin acts as an anti-diabetogenic factor and regulates and controls the normal blood sugar level.

(4) **Adreno-Corticotrophic Hormone** : It is liberated from anterior pituitary gland which acts upon adrenal cortex. This hormone controls the size and activity of adrenal cortex and regulates the secretion of glucocorticoid, mineralo-corticoid and sexocorticoid hormones. The gluco-corticoid hormone controls carbohydrate metabolism and normal blood sugar level, minearlocorticoid hormone controls mineral metabolism and the sexocorticoid hormone controls and regulates sex functions.

(5) **Adreno-medullotrophic Hormone** (?) : It is secreted from the anterior pituitary gland and acts upon adrenal medulla. This hormone helps in the secretion of adrenaline and noradrenaline from adrenal medulla which has got sympathetic in nature and catabolic in function.

(6) **Gonadotrophic Hormone** : The ganadotrophic hormone of anterior pituitary acts upon gonad. This hormone maintains the structure and functions of the gonads and controls the secretion of gonadotrophins. The gonadotrophins are of three types. They are Follicle Stimulating hormones or F. S. H. Luteinizing hormone or L. H. and Interstitial cell stimulating hormone or I.C.S.H. The follicle stimulating hormone helps in the formation of spermatogenesis in male and in the mauration of graafian follicle, process of ovulation and formation of Oogenesis in female. The luteinizing hormone helps in the formation of corpus luteum and progesterone hormone is liberated from there. The interstitial cell stimulating hormone acts upon interstitial cell of testis and ovary and helps in the formation of testosterone and androgen in male and oestrogen in female. respectively.

(7) **Growth Hormone** : This hormone is secreted by the eosinophil cells of the anterior pituitary. It controls skeletal growth, growth of the muscles and viscera and regulates general body growth. It has got an effect on protein metabolism and increases protein synthesis. It controls the time of fusion of epiphysis. This hormone helps in the formation of ketone bodies and thereby fat metabolism is regulated. It also controls corbohydrate metabolism and thereby it produces hyperglycaemia and glycosuria.

(8) **Lactogenic hormone** : This hormone is secreted by the eosinophil cells of the anterior pituitary. It is protein in nature. It induces the secretory changes in the breast leading to the initial growth and development of the mammary glands during pregnancy. It initiates, regulates and maintains the secretion and expulsion of milk.

(9) **Metabolic Hormone** : This hormone is secreted from

the anterior pituitary gland. It plays an important role in the regulation of carbohydrate and fat metabolism mainly through diabetogenic, ketogenic and insulin antagonising hormones.

Q. 3. Write what do you know about Gonadotrophic hormones.

The anterior pituitary secretes a hormone which on account of their action on sex glands are called gonadotrophic hormones or gonadotrophins. This hormone maintains the structure and functions of the gonads.

History : As a result of the work of *Smith* and *Engle* and also of *Zondek* and *Ascheim*, from 1927 onwards, a great deal has been learned about the controlling influence of the adenohypophysis on the ovary and testis.

Source : Gonadotrophins are produced by the anterior pituitary gland and by the chorion.

(a) *Hypophyseal Gonadotrophins* : These have been obtained from : (1) Hypophyseal extacts. (2) Urine of women in menopause or after castration. (3) Blood and urine of normal men and women.

(b) *Chorionic Gonadotrophins* : These are produced by the placenta and have been obtained from : (1) Urine and blood of pregnant women. (2) Blood of pregnant mares.

Classification : Gonadotrophins are classified into two main classes according to its origin.

(a) *Hypophyseal gonadotrophins* : These are again classified by Ascheim and Zondek in 1926 into three sub-classes :

(1) Prolan A or Follicle Stimulating hormone or F. S. H. or Follicular maturation factor or Gametogenic hormone.

(2) Prolan B or Interstitial cell-stimulating hormone or Luteinizing hormone or L. H.

(3) Luteotrophin or Prolactin or Mammogenic hormone or Mammogen I and Mammogen II.

(b) *Chorionic* or *Placental Gonadotropins*.

Description of Individual Gonadotropins :

I. **Effects of Hypophyseal Gonadotrophin in Male** : In some cases of ectopic testicle, injection of luteinizing or chorionic gonadotrophins cause the migration of testis into the scrotum. Injection of chorionic gonadotrophin in case of hypogonadism have been followed by stimulation of Leydig cells, secretion of male hormone takes place producing growth of penis and sexual hairs and oestrogen is excreted in the urine. The subsequent injection of F. S. H. has provoked spermatogenesis in the male individual.

II. **Effects of Hypophyseal Gonadotrophins in Female** : The effects of hypohyseal gonadotrophin on women are not well known. It has not been possible to maintain the menstrual cycle permanently or keep up a constant normal level. Large doses of gonadotrophins provoked a transitory increase in the secretion of oestrogen and the effects of hyperfunction of the corpus luteum. Injection of large doses of pregnant mare serum gonadotrophin, followed by the injection of chorionic gonadotrophin, it has been possible to provoke menstruation in many cases of amenorrhoea, ovulation has been obtained and in a few, pregnancy has resulted.

III. Effects of Follicle Stimulating Hormone :

(a) **In Male** : In the male, it maintains or restores the normal condition of the seminiferous epithelium of the testes and controls spermatogenesis.

(b) **In Female** : This hormone is responsible for the maturation, growth, ripening and dilatation of the graafian follicles, ovulation and the liberation of oestrin or dihydrooestrone. The ovaries stimulated by this anterior pituitary hormone brings about the psychic phenomenon of puberty and of the menstrual cycle of the post-pubertal life and as well as the physical changes in the accessory organs of the body.

IV. Effects of Luteinizing or Interstitial-cell stimulating Hormone :

(a) **In Male** : This hormone stimulates the interstitial tissue of Leydig in the normal and in the hypophysectomised males. It controls the secretory activity of the interstitial cells of the testes and the liberation of testosterone or male sex hormone with considerable development of the secondary sexual organs like prostate, seminal vesicles, etc. producing spermatogenesis in male.

(b) **In Female** : This hormone helps in the process of ovulation. It is responsible for luteinization or formation of corpus luteum and the liberation of progesterone hormone.

V. Effects of Luteotrophin or Prolactin : This hormone helps in the formation and secretion of milk from the mammary glands. Prolactin secretion begins after the complete evacuation of uterine content and therefore milk secretion starts after the birth of the baby.

VI. Effects of Placental or Chorionic Gonadotrophins : Gonadotrophins of placental origin have been found in the urine and blood of pregnant women and the serum of pregnant mares.

(*a*) **Urine and blood of pregnant women** : It is found in the urine of woman who have aborted while the placenta is retained in the uterus. It is eliminated in large quantities when there is tumor of placental origin like hydatiform mole or chorio-epithelioma and in certain cases of tumor on the testicle.

(*b*) **Serum of Pregnant mares** : The serum of pregnant mares has a very active gonadotrophin which is produced by special glandular structures of the placenta known as endometrial cups. It is protein in nature with great molecular weight and therefore it does not pass into the urine. It reaches its highest concentration between the fiftieth and eightieth day of pregnancy and then gradually diminishes.

Q. 4. What is Growth Hormone (Somatotrophic hormone)? Describe the physiological functions and disorders of growth hormone.

The growth hormone or somatotrophin is the direct hormone of anterior pituitary gland. This hormone is liberated from the eosinophil cells of pars distalis or pars anterior of Anterior pituitary gland. It controls skeletal growth and the time of fusion of epiphyses of long bones. It regulates growth of muscles and viscera of the general human body.

Physiological Functions : The growth hormone serves the following functions :

(*a*) **General body growth** : The growth hormone appears te be the stimulation of growth because it helps to increase the rate of growth of all growing cells of the body. There is also increased growth of the muscles and viscera. It stimulates the growth of the thymus and increases the secretion of milk during lactation.

(*b*) **Skeletal growth** : The growth hormone stimulates the multiplication of the epiphyseal cartilage and thus increases the length of the cartilage bones. In adult stage, growth hormons can cause the bones to grow considerably thicker than normal and most of the soft tissues of the body, including cartilage.

(*c*) **On Protein metabolism** : The growth hormone promotes the deposition of protein in the tissue throughout the body. This hormone increases protein synthesis and decreases nitrogen excretion in the urine. The growth hormone is protein-anabolic hormone and prevents the catabolism of amino-acids. This hormone increases the transport of amino-acids across the cell membrane and thus helps in the synthesis of protein.

(*d*) **On Fat metabolism** : This hormone helps in the formation of ketene bodies, the reserve fat becomes decreased and plasma lipid becomes increased.

(*e*) **On Carbohydrate metabolism** : The growth hormone increases the concentration of β-cells of the islets of Langerhans which is called the diabetogenic effect of growth hormone. In pancroectomised animal, removal of pituitary gland leads to hyperglycaemia, glycosuria and disappearance of ketone bodies and the animals live for months.

Disorders of Growth Hormone : The dysfunction of eosinophil cells of anterior pituitary produces disorders of growth hormone. During hyperfunction of growth hormone, *Gigantism* is produced in young life and *Acromegaly* is localised in post-pubertal life. During hypoactivity or less function of growth hormone, *Dwarfism* is produced in pre-pubertal or in young life and *Acromicria* is produced in post-pubertal or in adult life.

I. **Gigantism :** It is a type of giant caused by hyperactivity of the eosinophil cells of anterior pituitary in pre-pubertal life i.e. before the union of the epiphyses of long bones. It is characterised by morphological, physiological, psychological and sexological features.

(*a*) *Morphological Features* : (1) There will be considerable overgrowth in the length of the long bones. (2) The individual becomes very tall and 7 to 8 ft. in height. (3) Limbs are usually disproprtionately long. (4) The muscles and viscera are proportionately large. (5) Face looks like a young individual.

(*b*) *Physiological Features* : (1) There may be glycosuria i.e. sugar in the urine due to over action of diabetogenic hormone. (2) Reduced sugar tolerance. (3) Less calcium in the body. (4) Increased or raised basal metabolic rate.

(*c*) *Psychological Features* : The individual becomes intelligent.

(*d*) *Sexological Features* : Primary and accessory sex organs are not well developed. The sexual activity may be decreased.

II. **Acromegaly** : It is a type of disease produced by the hyperactivity of eosinophil cells of anterior pituitary in post-pubertal life i.e. after the union of the epiphyses of long bones, where there will be overgrowth of the skull, two jaws, the malar bones and the supra-orbital ridges. It is characterised by morphological, physiological psychological and sexological features.

(*a*) *Morphological Features* : (1) Ugly face and the individual more or less looks like a beast. (2) There will be overgrowth of skull, upper jaw, lower jaw, supra-orbital ridges and malar bones with separation of the teeth. (3) Bones of the hands and feet become grossly enlarged. (4) There will be kyphosis i.e., bowing of the spine due to overgrowth of the thoracic vertebrae. The antero-posterior diameter of the chest increases. (5) Enlargement of the viscera, the tongue, lungs, thymus, heart, liver, speen are greatly enlarged. (6) The subcutaneous tissues of the hands, feet, lips, nose and scalp become markedly thickened. (7) Skin becomes coarse, thick and inelastic producing deep furrows. (8) The thyroid, parathyroid and adrenal glands may show hypertrophy. (9) Nose may be broad, lips thick, tongue hypertrophied and colon enlarged.

(*b*) *Physiological Features* : (1) There may be glycosuria due to over action of diabetogenic hormone. (2) There may be hyperglycaemia and reduced sugar toleranee. (3) Less calcium in the body. (4) Increased basal metabolic rate. (5) There will be increased sweating from the sweat glands.

(c) *Psychological Features* : There will be mental disturbances. The individual is not so intelligent.

(d) *Sexological Features* : (1) Sexual function is depressed. (2) Atrophy of the goands causing impotency. (3) There will be amenorrhoea in women i.e., stoppage of menstruation before menopause and after puberty.

III. **Dwarfism** : It is a type of dwarf caused due to hypoactivity of the eosinophil cells of pituitary gland in pre-pubertal (young) life. It is characterised by morphological, physiological, psychological and sexological features.

(a) *Morphological Features* : (1) Skeletal growth becomes stunted and the adult individuals become 3 ft. high. (2) In adult dwarf, the face does not seem to be a young man and an adult man resembles a normal child.

(b) *Physiological Features* : (1) Basal metabolic rate is owered. (2) Low metabolism. (3) Less calcium in the blood. 4) There is gradually increasing weakness, a moderate degree of somnolence and slow pulse. (5) Accumulation of nitrogen product.

(c) *Psychological Features* : The individual possesses normal intelligence in proportion to age.

(d) *Sexological Features* : There will be loss of sexual desire, impotency or amenorrhoea due to lack of gonadotrophic hormones.

IV. **Acromicria** : It is a type of disease caused due to hypoactivity of the eosinophil cells of pituitary gland in post-pubertal (adult) life. It is characterised by morphological, physiological, psychological and sexological features.

(a) *Morphological Features* : (1) Flat bones and bones of the face, hands and feet are not well developed. (2) Some ridge formation takes place on the bones of the face. (3) Loss of hairs and cyanosis of the extremities. (4) In males, beard and axillary hairs are scanty, trunk and limbs are hairless and pubic hair is of feminine distribution.

(b) *Physiological Features* : (1) Low basal metabolic rate and reduced metabolism. (2) Less calcium in the blood and accumulation of nitrogen products.

(c) *Psychological Features* ; There will be mental backwardness. Some subjects are idiots.

(d) *Sexological Features* : There will be loss of sexual functions.

Q. 5. Describe the structure, active principle and functions of Porterior Pituitary.

Pituitary gland is the band master of endocrine orchestra and it controls different types of endocrine glands. The posterior lobe of pituitary gland regulates water balance, parturition (birth of a baby), blood pressure, metabolism and pigmentation of skin etc.

Anatomy : (Fig. 2) Pituitary, the small endocrine gland has 0·5 to 1 gm. in weight. Its average dimension are 10×13 ×6 sq. m.m. It is larger in females, specially in those who have brone children than in males. It constitutes a neural division known as pars nervosa and pars intermedia.

Development : The posterior pituitary is developed from the glandular diverticulum of the floor of the third ventricle which is ectodermal in origin. The pars intermedia develops from the posterior wall of Rathke's pouch (Adenohypophysis).

Histology : The posterior pituitary gland consists of pars nervosa and pars intermedia.

(*a*) **Pars Nervosa** : It consists of two types of cells and other nervous structures : (1) Mossy neuroglial cells, ependymal cells and mast cells. (2) Pituicytes or Fusiform cells : They are large branching, spindle-shaped cells containing granules of a brown pigment in their cytoplasm. The pituicytes consist of adenopituicytes, micropituicytes, fibropituicytes and reticulopituicytes. They are responsible for the production of porterior putuitary hormones. (3) Numerous nerve fibres from the supra-optic nucleus and a more posterior nucleus of the hypothalamus. (4) Hyaline bodies of Herring and blood vessels. (5) Mast cells.

(b) **Pars Intermedia** : It consists of : (1) Large cords of basophil cells which has no granules. (2) It often shows cysts of various sizes containing a hyaline or colloid material and a few cells filled up with some material like hyaline bodies.

Active Principle : The posterior pituitary gland secretes a number of hormones. The present conception is that the hormones of the posterior pituitary gland are therefore liberated at the nerve terminals of the supra-optico-hypophyseal tract. The crude extract of posterior pituitary gland is *pituitarin*.

(a) **From Pars Nervosa** : It is a neural structure which produces Oxytocin or Pitocin, Vasopressin or Pitressin, Antidiuretic hormone and Metabolic hormone.

(b) **From Pars Intermedia** : It liberates Intermedin or Melanophore stimulating hormone (MSH).

Functions of Posterior Pituitary hormones :

I. **Oxytocin (Pitocin)** : The hormone causes contraction of the plain muscles of the uterus and the mammary gland. It causes contraction of the uterus during the later part of pregnancy. Towards the later part of pregnancy, placenta and corpus luteum do not secrete any progesterone. The progesterone level in the blood is diminished and so oxytocin causes contraction of the uterus to expel the foetus and placenta from the uterus

The oxytocin hormone also causes contraction of the plain muscles lining the alveoli of the mammary gland and thereby helps in the expulsion of milk from the mammary gland. This hormone produces hyperglycaemia in large doses specially in dogs.

II. **Vasopressin (Pitressin)** : It causes contraction of all the blood vessels of the body and as a result there will be rise of blood pressure.

Coronary vessels are constricted and the cardiac muscles do not get proper nutrition. If pituitarin is injected repeatedly, there will be fall of blood pressure.

The hormone will cause contraction of the plain muscles of the intestine, gall bladder, urinary bladder etc. This hormone increases the peristaltic movement of the stomach and intestine, contraction of the trachea and bronchous and contraction of the gall bladder and detrusor muscles of the urinary bladder.

III. **Anti-diuretic Hormone** : (A.D.H.) : This hormone regulates the output of urine from kidney and thereby regulates the water volume of the body. 170 litres of water are being filtered through the glomerulus into the Bowman's capsule in 24 hours. Out of this 170 litres, 168·5 litres are reabsorbed back into the blood from the kidney tubules. Water is reabsorbed both from the proximal and distal part of the kidney tubules. This hormone regulates the reabsorption of water from the distal part of the tubules. This hormone reduces chloride absorption and increases chloride loss. It causes contraction of all the plain muscles of the body excepting those of heart and uterus.

IV. **Metabolic Hormone** : This hormone mainly acts upon carbohydrate metabolism by hyperglycaemia, glycosuria, low sugar tolerance, loss of liver glycogen due to the increased formation of liver glycogen and low basal metabolic rate.

V. **Melanophore Stimulating Hormone** (Intermedin) : This hormone is secreted from pars intermedia of the posterior lobe of the pituitary gland. As it is secreted from intermedia, so it is known as intermedin. There are two types of melanophore-stimulating hormone like α and β present in pituitaries of ox, pig, horse, monkey and human beings. It is concerned with the change of complexion of animals. The melanophoric hormone acts upon melanophores, the pigmented cells present in the epidermal layer of skin of animals like amphibia and fishes. These melanophores expand and produce the dark colouration of the skin. The melanophores are absent in human being but are present in fishes and amphibia. It can be detected in the urine of both men and women and during pregnancy it increases.

Q. 6. Describe the structure, active principle and functions of Thyroid gland.

Thyroid gland is a shield shaped structure, situated just infront of the trachea and liberates thyroxine that maintains and regulates iodine balance of the body.

Situation : Thyroid gland is situated just infront or below the thyroid cartilage and infront of the trachea. In otherwords, it is situated in the tracheo-laryngeal junction.

Anatomy : Thyroid gland possesses two leteral lobes, one on each side of the trachea and is connected at the middle by isthmus crossing infront of the 2nd, 3rd and 4th tracheal rings. These are two oval shaped bodies, highly vascular and weighing about 20 to 40 gms. in adult human being.

Development : The thyroid gland is developed from a single median outgrowth of hypoblast derived from the ventral wall of the primitive pharynx at the level of first cervical cleft. This extends downwards. Its lower end bifurcates and enlarges to form the *isthmus* and lateral lobes of thyroid.

Histology : The outer covering of the thyroid gland is known as fibrous capsule from which trabeculae will run into the substance of the gland dividing it into several compartments. In the compartment, there are vesicles or follicles. Each vesicle is lined by single layer of cubical epithelial cells in which there are mitochondria and golgi bodies. The vesicles contain a homogeneous, viscid, semifluid, complex and slightly yellowish, colloid material secreted by the lining epithelial cells. There is no basement membrane so that the epithelial cells are in direct contact with the connective tissue frame work. The parafollicular cells, lymphoid cells and macrophages are seen in between the vesicles. Three types of follicles can be distinguished by special staining methods like basophilic, acidophilic and mixed. The interstitial tissue will contain blood vessels, lymphatics and nerve fitres.

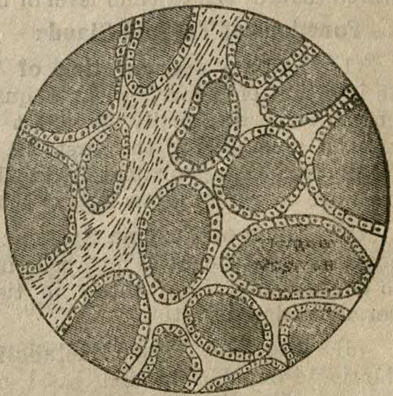


Fig. 4. Histological Structures of Thyroid Gland.

Active Principle : The active principles of the thyroid gland are *Thyroxine* and *Thyrocalcitonin.* Chemically, thyroxine is Para-hydroxy-phenyl ether of Tyrosine with four atoms of Iodine.

(a) **Thyroxine Formation** : The process of thyroxine formation from the thyroid gland is as follows :

Thyroid vesicle
↓
Thyroglobulin
↓
Tyrosine + $4I_2$
↓
Diiodotyrosine
+
Diiodotyrosine
↓
Thyroxine
+
Alanine

The thyroid gland will take Iodine in the form of inorganic iodine from the blood plasma. This inorganic iodine will liberate free Iodine with the enzyme peroxidase. The thyroid gland will also take amino-acid Tyrosine from the blood which will combine with Iodine to form di-iodotyrosine. Two molecules of di-iodotyrosine combine together to form Thyroxine and alanine is eliminated. This Thyroxine combines with globin and the vesicles as Thyroglobulin which is known as colloidal material. The thyrotrophic hormone of anterior pituitary acts as proteolytic enzyme and splits the colloidmaterial into Thyroxine and globulin.

(b) **Thyrocalcitonin Formation** : The mitochondrial-rich cells which are lesser in number and present in between the follicular epithelial cells of Thyroid gland. These cells help in the synthesis of a hormone known as ***Thyrocalcitonin*** (T.C.T,) which reduces the calcium level of blood.

Functions of Thyroid Gland :

(1) **Latency and duration of Thyroxine activity** : After an injection of relatively large quantity of Thyroxine in the human being, essentially no effect on the rate of metabolism can be seen during the first 24 hours, the action becomes maximum after approximately 8 to 12 days, the action of the hormone continues for as long as 1 to 2 months.

(2) **Effect on Enzyme System** : Atleast thirteen different enzymes of considerable metabolic importance have been shown to be increased in quantity in tissue cells following thyroid hormone administration.

(3) **Effect on Tissue Metabolism** : Thyroxine stimulates the tissue metabolism and basal metabolic rate is increased. It profoundly stimulates general metabolic activities of the body in all ages.

(4) **Effect on Cardiovascular System** : The force and frequency of the heart beat will be increased when cardiac output and blood pressure will be increased. Thyroxine will stimulate the cardiac musculature directly to increase the heart rate.

(5) **Effect on Gastro-intestinal Tract** : Thyroxine stimulates the absorption of glucose from small intestines and will produce hyperglycaemia and glycosuria.

(6) **Effect on Carbohydrate Metabolism** : The Thyroxine hormone oxidises sugar, mobilises glycogen, reduces sugar tolerence and may cause hyperglycaemia and glycosuria.

(7) **Effect on Fat Metabolism** : The Thyroxine hormone will increase the oxidation of fat and injection of this hormone will cause loss of depot fat.

(8) **Effect on Protein Metabolism** : The rates of both protein anabolism and catabolism appear to be increased by thyroxine which is the effect to be expected because of the increased enzymatic activities in the cells.

(9) **Effect on Vitamin Metabolism** : Because thyroxine increases the quantity of many of the different enzymes and because vitamins are essential part of some of the systems, thyroxine causes increased need for vitamins.

(10) **Effect on Calcium Metabolism** : Thyroxine causes increased metabolism of calcium from the bone and injection of thyroxine will produce osteoporosis by stimulating the activity of the osteoclast cells.

(11) **Effect on Iodine Metabolism** : Thyroxine causes in the absorption of inorganic iodide from the blood. This inorganic iodide liberates free iodine and combines with tyrosine forming di-iodotyrosine which subsquently transform into thyroxine.

(12) **Effect on Kidney** : Thyroxine will cause increased urinary output and more urine will excrete out. The increased urinary output is due to the rise of blood pressure which will cause rise of effective filtration pressure in the glomerulus.

(13) **Effect on Red Cell Formation** : Thyroxine is responsible for the formation of haemoglobin and for bringing about the maturation of blood cells.

(14) **Effect on Temperature Regulation** : Thyroxine takes part in the regulation of normal body temperature. Less thyroxine formation increases susceptibility to cold.

(15) **Effect on Cellular Metamorphosis** : The injection of Thyroxine to the tadpole larva will convert the tadpoles into the frogs within a very short time and thereby it stimulates cellular metamorphosis.

(16) **Effect on Respiration** : Thyroxine increases rate of respiration. This increased rate of respiration is due to the rise of body temperature caused by increased tissue metabolism.

Q. 7. Describe the formation, synthesis, mode of action and fate of Thyroxine. What are Anti-Thyroid drugs ?

Thyroxine is one of the active principle of Thyroid gland. The anterior pituitary manufactures Thyrotrophic hormone which acts upon Thyroid gland and helps in the liberation of Thyroxine.

Formation of Thyroxine : Thyroid gland manufactures thyroxine from inorganic iodide and tyrosine. This gland will take Iodine in the form of inorganic iodide from the blood plasma. This inorganic iodide will liberate free iodine with the help of an enzyme known as peroxidase. The thyroid gland will also take amino-acid Tyrosine from the blood which will combine with iodine to form 3-monoiodo-tyrosine and 3 : 5—diiodotyrosine. Two molecules of diidotyrosine combine together to form Thyroxine and alanine is eliminated. This thyroxine combines with globin and either is stored in the vesicles in combination with a protein molecule as Thyroglobulin or it is released into the blood stream. The thyrotrophic hormone of anterior pituitary acts as proteolytic enzyme and splits the colloid material, Thyroglobulin into Thyroxine and globulin.

Synthesis of Thyroxine : The stages of thyroxine synthesis have been studied by giving radio-active iodine ^{131}I with a half life of 8 days as tracer element. The uptake of Iodine from blood is taken up by cubical epithelial cells under the influence of T.S.H as inorganic iodine. The enzyme "peroxidase" belonging to cytochrome enzyme system liberates free Iodine. The cell cytoplasm containing protein contained amino-acid Tyrosine conjugates with Iodine to give rise to di-iodo tyrosine. Two molecules of di-iodo-tyrosine conjugate together to give rise to thyroxine and alanine. In the synthesis of tri-iodo-tyrosine, tyrosine conjugates with Iodine to form mono-iodo tyrosine. The monoiodo-tyrosine conjugates again with Iodine to form di-iodotyrosine. Then one molecule of monoiodotyrosine conjugates with one molecule of di-iodo-tyrosine to give rise to tri-iodo-thyronine and alanine. The cubical epithelial cell will therefore secrete both Tetra-iodo-thyronine and Tri-iodo-thyronine through proteolytic hydrolysis by proteolytic enzyme. Simultaneously, 3-monoiodotyrosine and 3 : 5 diiodotyrosine are also split up by specific enzyme and iodine thus liberated helps in further synthesis of thyroxine.

Mode of Action of Thyroxine :

(a) **Energy production** : Thyroxine increases energy and oxygen consumption of tissues.

(b) **Metabolism** : (1) It increases carbohydrate metabolism by stimulating absorption of glucose, mobilising glycogen from heart and liver, promoting neoglucogenesis, causing hyperglycaemia and reduces sugar tolerence. (2) It helps in protein metabolism by stimulating the breakdown of protein specially in skeletal muscles. (3) It promotes calcium and phosphorus metabolism by removing calcium and phosphorous from the bones leading to osteoporosis.

(c) **Excretion** : It increases excretion of nitrogen and creatine through the kidney.

(d) **Body growth** : Thyroxine promotes growth of the body of an individual.

(e) **Heart Rate** ; It acts directly on the heart and accelerates the rate of the heart.

Fate of Thyroxine : Thyroxine after circulating in the blood stream, enter into the liver and is excreted in the bile partly as free thyroxine and partly as glucuronide. The glucuronide is hydrolysed in the intestine by the bacteria and Thyroxine is liberated. It is partly reabsorbed in the blood stream and partly excreted in the faeces.

Anti-Thyroid Drugs : The anti-thyroid drugs are those drugs which do not help in the synthesis of Thyroxine formation. They are Thyocyanates, Thiourea, Thiouracil, Sulphaguanidine, P.A.B.A. and Radio-active iodine. The mode of action of anti-thyroid drugs are the following : (1) The drugs like Thyocyanates may prevent the concentration of iodine. (2) The drugs like Thiourea and Thiouracil may prevent the conjugation of Iodine with the amino-acid Tyrosine to give rise to di-iodotyrosine. (3) The drugs like Sulphaguanidine, P.A.B.A (Para-Amino-Benzoic acid) may prevent the conjugation of two molecules of Di-iodotyrosine to give rise to thyroxine. (4) The drugs like Radio-active iodine may destroy the cubical epithelial cells for the Thyroid gland and thereby there will be no formation of Thyroxine.

Q. 8. Discuss what do you know about hyperfunctions and hypofunctions of Thyroid Gland.

Thyroid gland liberates Thyroxine by the action of Thyrotrophic hormone of Anterior pituitary and synthesises an another hormone known as Thyrocalcitonin. The hypothyroidism or less secretion of thyroxine hormone produces *Cretinism* in young age and *Myxoedema* in adults. The hyperthyroidism or increased formation of thyroxine produces *Grave's Disease* or *Exophthalmic Goitre* both in young and adult stage of life.

1. CRETINISM : A cretin is a type of dwarf found in hypofunction of Thyroid gland in young age.

Causes : The cretinism is caused due to the absence or less secretion of Thyroxine hormone in infancy or in early childhood.

Features : A cretin is characterised by morphological, physiological, psychological and sexological features.

(A) **Morphological Features** :

(1) **Milestones of Child's Development** : The developments of holding up the head in three months, sitting posture and dentition in six to seven months, closure of anterior fontanelle in five months, standing, walking and speech in twelve to eighteen months, are all delayed.

(2) **Shape** : Dwarf in shape and the cretin individuals become short in stature.

(3) **Skeleton** : Retarted or stunted skeletal growth and the epiphysis of the long bones fails to ossify at the usual time. The bones grow in thickness but not in length, short club-like fingers with deformed bones and teeth, delayed union of structures of the cranial bones and anterior and posterior frontanalle.

(4) **Skin** : Rough, dry, thick, wrinkled and pasty skin and there is deposition of fat in supra-clavicular fossa, scanty growth of hairs.

(5) **Face** : Coarse and bloated facial appearance, idiotic look, thick parted lips, nose broadened with depressed bridge, tongue thickened, enlarged and prolonged out and saliva dribbles out constantly.

(6) **Muscles** : The capacity of muscular activity is greatly diminished and there is poor growth of muscles.

(7) **Abdomen** : Pot-bellied abdomen with enlarged liver and umbilicus sometime comes out or protruding or everted.

(B) **Physiological Features** : (1) Decreased heart rate, diminished cardiac output, fall of blood pressure and diminished pulmonary ventilation. (2) Low blood sugar, high sugar tolerance, high serum cholesterol and low blood iodine. There will be diminished count of red blood cells. (3) Increased storage of glycogen in the liver and decreased absorption of glucose from the intestine. (4) The basal metabolic rate is lowered by 20% to 40% and low body temperature. The child is susceptible to cold, toxins and intercurrent infections.

(C) **Psychological Features** : The individuals become dull, idiotic and complete lack of intelligence and often deaf and dumb.

(D) **Sexological Features** : There will be arrested growth of sex glands and sex organs. The secondary sexual characters are ill-developed and have delayed appearance.

II. **MYXOEDEMA (Gull's Disease)** : It is a type of disease by which the individuals possess yellow in colouration due to the deposition of myxoematous tissue found in hypofunction of Thyroid gland in adult life.

Causes : This disease is caused in adult individual by the hypothyroid function occupying in the post-pubertal stage of life. It follows atrophy or destruction of the Thyroid gland from whatever cause or may result from an operation in which too much of the Thyroid gland has been removed.

Features : The disease Myxoedema is characterised by morphological, physiological, psychological and sexological features.

(A) **Morphological Features** :

(1) **Colour** : The subject becomes yellow and waxy in colouration due to the deposition of myxoematous tissue.

(2) **Skin** : A thick puffy appearance of the skin due to the deposition of a semifluid albuminous substance which is rich in proteins and muco-polysaccharides. Hairs dry, brittle, sparse and fallen off from axilla, pubis, head and outer third of eyebrows. The sub-cutaneous tissue will increase and it becomes hard and thick.

(3) **Face** : Swollen, puffy, pale, oedematous face and sometimes give the subject, a mongoloid look. The paleness is due to the diminished red cell count. There will be swelling of tongue and larynx.

(4) **Neck** : There may be swelling or may not be any swelling in the neck region.

(5) **Body** : The peculiar deposition of fat is distributed in the clavicular region, axillary region, buttak region, etc. The accumulation of myxoedematous tissue is increased over supraclavicular fossa. There will be weakness and pain in joints and muscles of the body.

(B) **Physiological Features** : (1) Diminished cardiac output, fall of heart rate, slow stroke volume and minute volume, transverse enlargement of the heart, low blood pressure and blood volume is lowered. (2) The basal metabolic rate is diminished by 30% to 45%, body temperature sub-normal, the subject feels cold excessively and increased susceptibility to cold. (3) Diminished red cell count, hypoglycaemia, cholesterol content increased above 300 mgm% and diminished urinary output. (4) Low blood sugar and iodine, increased sugar tolerance, rise of plasma protein and less nitrogen excretion form the body. (5) There will be diminished peristaltic movement of the gastro-intestinal tract and as a result there will be loss of appetite. There is often constipation may occur.

(C) **Psychological Features** : There will be diminished mental process, apathy, lethergy, low cerebration, slowness of thought, sluggish movement, loss of memory, dullness, easy fatigue, hoarseness of voice and slow slurring speech and somnolence, etc.

(D) **Sexological Features** : The sexual functions are diminished and primary sexual glands and organs are degenerated. There will be impotency (loss of sexual power and activity) in male and amenorrhoea (absence of menstruation before menopause and after puberty) in female.

III. **GRAVES' DISEASE (Exophthalmic Goitre)** : It is a grave condition of an individual during excess secretion of Thyroxine from Thyroid gland where the protrusion of eyeball takes place from the orbit.

Causes : This disease is caused due to increased secretion of Thyroxine from the Thyroid gland in infancy and adult life. The goitre is produced by the hyperthyroidism condition in which *Exophthalmic goitre* is one of the type.

Features : The Graves' disease of an individual is characterised by morphological, physiological, psychological and sexological features.

(A) **Morphological Features** :

(1) **Body** : The individual with enlarged thyroid gland has got loss of depot fat in the body. The body weight is decreased.

(2) **Skin** : It becomes soft, smooth, moist, glossy, shiny and flushed due to vasodilatation helping heat loss. The cutaneous arterioles are relaxed.

(3) **Neck** : There will be swelling in the neck region due to the enlargement of thyroid gland.

(4) **Eye Signs** : (i) *Exophthalmos* : It is a condition of protrusion or forward displacement of the eyeball with a "staring look" and less twinkling of eyelids. (ii) *Retraction of the Upper Eyelids* : It is caused by infiltration of fat in the levator palpebral superioris muscle, contraction of the tarsal muscle and dilatation of the pupil. (iii) *Ophthalmoplegia* : It is a condition of the weakness of the external ocular muscles caused due to the excessive deposition of fat in these muscles which show round cell infiltration and degeneration.

(5) **Voluntary Muscle** : A fine tremor of the skeletal muscles is present due to the removal of calcium from the body through the urine and faeces. The muscles become easily fatigued and there will be increased ankle jerk and muscular weakness.

(6) **Bones** : There will be osteoporosis of the bones due to increased mobilisation of calcium from the bone and excessive loss of calcium and phosphorous.

(B) **Physiological Features** : (1) There will be increased force and frequency of the heart beat (Tachycardia), increased cardiac output, rise of blood pressure and increased pulmonary ventilation causing foree and frequency of breathing. (2) There will be increased breakdown of liver glycogen into glucose from the small intentine. (3) There will be increased urinary output, glycosuria may occur, increased urea excretion and there will be creatinurea. (4) The Electroencephaologram shows abnormal α-waves. (5) There will be increased peristaltic movement of the stomach and intestine and thereby appetite is increased. (6) There will be mobilisation of depot fat and ketone bodies are produced more. (7) The basal metabolic rate is enormously increased from 40% to 100%. There will be increased vitamin need specially vitamin A, B and C. (8) There will be increased red cell count and hyperglycaemia, cholesterol content is diminished and increased iodine content in the blood.

(C) **Psychological Features** : The mental condition is at first smart, sharp but after sometime the individual becomes emotional and slightly restless. There will be acute nervousness and irritability.

(D) **Sexological Features** : There will be Impotency in male and Amenorrhoea in female. The menorrhagia may occur in female and finally there may be complete stoppage of menstruation.

Q. 9. Describe the structure, active principle and physiological actions of Parathyroid Gland.

The parthyroid glands are one of the endocrine glands situated at the posterior aspect of the thyroid mass, four in number and liberates parathormone that regulates normal calcium and phosphorus level in the blood.

Situation : The two parathyroid glands are situated on each side on the posterior surface of the lateral aspect of the thyroid gland or it may be actually embedded in its substance.

Development : The parathyriod glands are developed from third and fourth branchial pouch which are ectodermal in origin.

Anatomy : The parathyroid glands are small, globular bean-shaped, yellowish red organs, four in number, placed behind the thyroid gland. Out of four glands two lie on the upper border of the lateral lobes of the thyroid gland known as *External* or *Parathyroid* IV and the other two glands lie on the lower border of the thyroid gland known as *Internal* or *Parathyroid* III. The dimension of this gland is 6 × 3 × 2 m.m., total weight becomes 140 mgm.

Histology : The parathyroid gland is composed of large, solid, round epithelial cells closely packed together into columns of connective tissue masses separated by blood sinusoids. The cells do not show any alveolar arrangement. The following types of cells are present in the parathyroid gland.

(1) **Chief Cells or Principal Cells.** These are clear secretory cells contain large vesicular nuclei, the protoplasm stains poorly and are usually non-granular but they are the secretory cells of the parathyroid gland. These cells are present in the human gland upto tenth year of life.

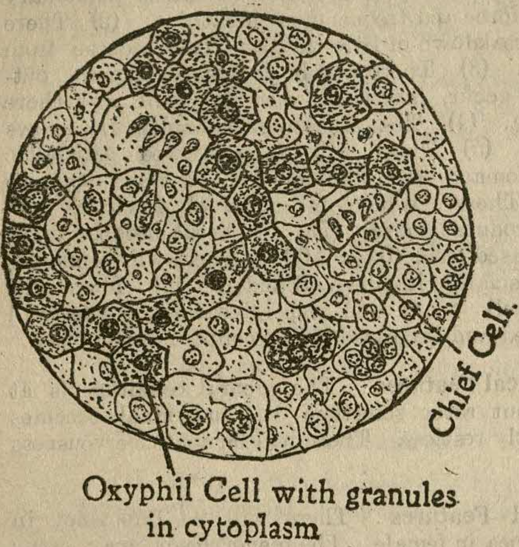


Fig. 5. Histological Structure of Parathyroid Gland

(2) **Oxyphil Cells or Eosinophil Cells** : These cells are polyhedral in nature and larger than the preceeding one and contain granules in their cytoplasm and lack of glycogen. The granules are stained with eosin and other acid dyes and they do not appear in the human gland until after the tenth year of life.

(3) **Intermediate types of Cells** : These cells are intermediate between Chief cells and Eosinophil cells with finely granular pale eosinophilic cytoplasm and darker nucleus.

Active Principle : The active principle of parathyroid gland is *parthormone* which is protein in nature and therefore cannot be administered orally. The parathyrotrophic hormone of anterior pituitary acts on parathyroid gland and parathormone is liberated. This hormone is composed of a huge number of amino-acid residues.

Physiological Actions or Functions of Parathyroid Gland :

(1) The parathormone regulates the normal level of calcium and phosphorous in the blood and the bones and with the help of kidney. This hormone helps in the reabsorption of calcium from the kidney tubules and excretion of phosphorous with the urine through the kidney.

(2) This hormone acts as a calcium solvent and thereby it helps for the solubility of calcium in the blood.

(3) The parathormone has got direct action on bones. When this hormone is administered in the body, the blood calcium level rises due to the mobilisation of calcium from the bones. This hormone stimulates the activity of osteoclast cells which will cause increased mobilisation of calcium from the bone producing multiple cavities within the bone known as *osteitis fibrosa cystica.*

(4) The parathormone of the parathyroid gland is essential for life.

(5) It regulates creatine metabolism in muscle. In hypoparathyroidism, creatine phosphate in muscles diminishes and guanidine bodies in blood increases.

(6) It regulates the permeability of blood vessels.

(7) Parathormone is essential in the vitamin D metabolism and makes an interrelationship in between parathormone and vitamin D.

Q. 10. Describe the manifestations of hopofunction and hyperfunction of Parathyroid gland.

The parathyroid glands liberate parathormone by the activation of parathyrotrophic hormone of anterior pituitary. Due to excess or lack of parathormone, the different manifestations produced which are discussed below :

I. Hypofunction of Parathyroid Gland. (Effect of Parathyroidectomy).

The decerased parathormone production from the parathyroid gland causes the following manifestations :

(a) The fall of serum calcium level from normal 10 mgm to 6 mgm per 100 ml. of blood and rise of inorganic phosphate in the blood from normal 5 mgm. to 8 mgm. per 100 ml. of blood and increase of guanidine bodies.

(b) The calcium excretion with the urine is increased and phosphate excretion will be diminished.

(c) Due to the diminution of calcium level in the blood there will be increased neuromuscular excitability causing **Tetany** in man. There is hyperexcitability in the peripheral nerves, twitching of the muscles, extensor stiffness in the legs and death may occur due to asphyxia. Tetany is more servere in young that in old persons, in carnivora than in herbivora, in pregnancy, lactation and with high protein diet. The features of *Tetany* caused due to hypoparathyroidism are the following :

(1) A very weak current which is ineffective in producing contraction of a muscle of a healthy person but it is effective in producing contraction on the muscle suffering from Hypoparathyroidsim.

(2) **Carpopedal Spasm** : (i) *Carpal Spasm* : There will be flexion at the wrist joint, flexion at the metacarpo-phalangeal joint, extension of the inter-phalangeal joints and adduction of the thumb. (ii) *Pedal Spasm* : It is the dorsiflexion of the ankle joint and planter flexion of the toes.

(3) **Laryngismus Stridulus** : There is sudden spasmodic contraction of the respiratory passage. Cyanosis will develop spontaneously and there will be relaxation of the laryngeal muscles causing normal breathing with a peculiar crowing sound.

(4) **Trousseau's Sign** : Occlusion of the circulation in the fore arm by means of blood press armlet cause the hand to assume the typical attitude known as *Carpal spasm* or *Accucheur's hand* or *Obstetrician hand.*

(5) **Chvostek's Sign** : Tapping the facial nerve near the styloid process and infront of the ear will produce spasmodic contraction of the muscles of the face.

(6) **Erb's Sign** : The galvanic current causes increased excitability of motor nerves.

(7) The Rheobase is lower and Chronaxie is higher than in normal subjects.

(8) Hyperpnoea of few minutes duration provokes muscular twitchings and convulsions in subjects with latent tetany, owing to alkalosis.

(d) The cataract i.e., opacity of the eye lens is gradually established in prolonged hypocalcemia.

(e) The dental lesions are marked in infantile tetany. The teeth take on a dull white aspect and later brown stains appear. The enamel is hypoplastic.

(f) The bone lesions are not prominent, but ossification is delayed in young animals and consolidation of fractures is retarded in adults.

(g) There will be deficient development of hair and nails. The nails are easily broken and the hair falls.

(h) Cutaneous disturbances such as erosion and ulcerations are sometimes observed.

II. **Hyperfunction of Parathyroid Gland** : The increased parathormone production from the parathyroid gland causes the following manifestations:

(1) The calcium level in the blood will be increased and phosphorous level will be diminished. The calcium level may be upto 20 mgm. per 100 ml. and phosphorus level may be upto 23 mgm. per 100 ml.

(2) The calcium excretion with the urine will be diminished and phosphorous excretion will be increased.

(3) Increased mobilisation of calcium from the bone producing multiple cavities in the bone and the condition is known as *osteitis-fibrosa-cystica.*

(4) There will be nausea, vomiting, drousiness, loss of appetite, loss of muscular tone and polyuria.

(5) There is constant drowsiness due to depression of the central nervous system.

(6) There is less neuro-muscular excitability and a strong current which is greater than the threshold one will produce the excitation of the muscles.

Q. 11. Describe the role of Parathormone on Calcium and Phosphorus metabolism.

The parathyroid gland secretes a hormone known as parathormone which regulates calcium and phosphate metabolism. It controls the blood calcium and blood phosphorus level.

Blood Calcium Level : The normal range of calcium in the blood becomes 9 to 11 mgm. per 100 ml. of blood. It is present in the blood in diffusible and non-diffusible forms. The diffusible form of calcium remains in the ionised form (4·8 to 6·3 mgm. per 100 ml. of blood) and non-ionised form (0·25 to 0·50 mgm. per 100 ml. of blood). The non-diffusible form of calcium remains in combination with protein and becomes 4 to 5 mgm. per 100 ml. of blood.

Blood Phosphorus Level : The normal range of phosphorus in the blood becomes 4 to 6 mgm. per 100 ml. of blood. The phosphorus present in the blood as a form of inorganic and organic phosphates. The inorganic phosphate is distributed equally between plasma and corpuscles and the range becomes 2·5 to 4·5 mgm. per 100 ml. of blood. The organic phosphate is present in large quantities in the form of phospholipids (lecithin, etc) and also as ester phosphorus are found in the red cells.

Role of Parathormone on Blood Calcium and Blood Phosphorus Level : The parathormone of the parathyroid gland regulates calcium and phosphate metabolism. The hormone helps to raise the plasma calcium level by increasing re-absorption of calcium from the renal tubules and by mobilisation of calcium and phosphate from the bones causing osteoporosis. The excess amount of phosphate is excreted in the urine and thereby the plasma phosphate level falls. This hormone helps to release both calcium and phosphte from the bones that are mixed into the circulating blood and at the same time, the parathormone stimulates the renal tubules to excrete phosphate. The ultimate result is that there is a rise in serum calcium and fall in plasma phosphate. The parathormone also increases the absorption of calcium from the intestine.

In hyperparathyroidism, the parathormone is liberated in increased amount which will stimulate the osteoblast cells of the bone and thereby the more calcium and phosphate are deposited in the bones, teeth etc.

In hypoparathyroidsm, the parathormone is liberated in decreased amount which will stimulate the osteoclast cell of bone that will help to remove both calcium and phosphate from the bones. The renal threshold for calcium is raised but that of plasma phosphate is lowered, resulting in hypercalcaemia and hypophosphataemia. Due to the removal of more calcium and phosphate from the bone, there will be the formation of osteoporosis in general and osteomalacia in female.

By maintaining the normal phosphorus and calcium ratio in the blood and by maintaining the product constant, the hormone helps in the proper growth or ossification of the bones.

Q. 12. Describe the structure of the Islets of Langerhans and discuss the source, composition of Insulin. Discuss the physiological actions (functions) of the different hormones of the Pancreas.

Pancreas is a tubulo-racemose gland, situated within the second part of the duodenum and lies across the vertebral column with a duct to carry the external secretion rich in enzyme and delt with in connection with the digestive system. The central part of the pancreas formed by the islets cells of Langerhans, responsible for the internal secretion known as Insulin which acts as an anti-diabetogenic factor.

Development : The Islets of Langerhans develops as buds from the hollow outgrowthed ducts and remain as solid clumps of cells. During development in most cases, the connections with the duct vanishes and the islets become completely isolated.

Structure of the Islets cells : These are small irregular collections of epithelial cells with no ducts and found scattered between the alveoli of the pancreas. The cells are more or less polyhedral in shape. By intravitum staining with neutral red, two kinds of cells may be distinguished by colour reaction of the cell granules. The islets cells are of four types, known as α, β, γ and δ cells.

(a) **α-cell** (20%) : This cell contains oxyphil granules. These granules are fixed in alcoholic solutions. According to *Dragstedt*. this cell is responsible for the formation of a hormone known as *Lipocaic* resembling choline in action, preventing fatty changes in the liver. The alpha-cells probably secrete *glucagon.* It is polypeptide in nature which on injection causes hyperglycaemia.

(b) **β-cell** (70%-80%) : This cell contains basophil gnanules which occupy the periphery of the islets and are smaller than the other. It is the producer of the anti-diabetogenic hormone known as *Insulin.*

(c) **γ-cell** : These cells are non-granular and non-staining and believed to be the precusors of α and β cells.

(d) **δ-cell** : According to *Bloom,* δ-cells have been seen only in human pancreas and are not well-defined. They are non-granular and non staining.

Source of Insulin : The main points of evidence which indicate that the hormone Insulin is produced in the islets cells are as follows :

(a) Histologically, the islets are glandular structure, the obvious outlets for the secretion of which is through the blood stream.

(b) The clinical condition known as hyperinsulism occurs from the pancreas liberates abnormally large amounts of anti-diabetogenic hormone.

(c) Metastases in other tissues arising from carcinoma of the islets cells have been shown to contain insulin.

(d) The injection of anterior pituitary extract leads to destructive changes in the islets cells, chiefly in the β-cell, while there is little or no effect on the α-cell.

Composition of Insulin :

(A) **Physical Properties** :

(1) Molecular weight : It becomes 48,000.

(2) Hydrogen-ion-concentration : 7·0 to 7·5.

(3) Protein Concentration : 0·4 to 0·9%.

(4) Emperical formula : It becomes $C_{45}H_{69}O_{14}N_{12}S$,

(5) Ordinarily, insulin is white amorphous powder soluble in water.

(6) It is activated by alkaline solution even at the bodytemperature.

(B) **Chemical Composition** : Insulin when hydrolised, yields a mixture of amino-acids which are as follows :

(a) *Amino-acids* : Leucine 30%, Glutamic acid 21%, Cystine 12·5%, Tyrosine and Phenylanine 11%. Proline 10%, Histidine 4%, Serine 3·2%, Arginine, 3·2%, Threonine 2·7%, Lysine, 2·3% etc.

(b) *Zinc* : 0·3 to 0·6%.

Physiological Actions or Functions of the hormones of the Pancreas : The hormones of the pancreas are Glucagon or H-G factor, Lipocaic and Insulin.

I. **Functions of Glucagon or H-G Factor** :

The Physiological action of glucagon is similar to that of adrenaline and thereby it stimulates the breakdown of liver glycogen into glucose. The injection of glucagon will therefore produces hyperglycaemia which will lead to glycosuria when the blood sugar level becomes more than 180 mg. per 100 ml. of blood.

II, Functions of Insulin :

(a) **On Carbohydrate Metabolism** : The insulin regulates the carbohydrate metabolism by the following processes :

1. *Glycogen Metabolism* : The insulin stimulates glycogenesis and prevents glycogenolysis. The glycogen can be formed from glucose by isolated tissue if the appropriate phosphorylating and condensing enzyme systems are present.

2. *Combustion of Glucose* : The combustion of sugar is increased by insulin in the tissues and helps in the transport of glucose into the cells.

3. *Neoglucogenesis* : The insulin regulates hepatic neoglucogenesis i.e., the net formation of glucose from non-carbohydrate sources.

(b) **On Fat Metabolism** : The insulin stimulates lipogenesis i.e. it helps in the accumulation of depot fat. As insulin stimulates the oxidation of glucose, administration of insulin will produce oxidation of gulcose to supply the energy and heat. they will be deposited in the body as depot fat.

(c) **On Protein Metabolism** : The insulin stimulates the synthesis of tissue protein and thereby helps in the growth of the tissues.

(d) **On Respiratory Quotient** : The R. Q. on mixed diet is 0·85. The injection of insulin will stimulate oxidation of glucose to liberate energy and heat and thereby R. Q. is increased.

III. **Functions of Lipocaic** : The hormone *lipocaic* is liberated from the alpha-cells of Istets of Langerhans of Pancreas. It prevents fatty degeneration of the liver.

Q. 13. Describe the structure, active principle and physiological functions of Adrenal Cortex.

The supra-renal gland or adrenal gland is situated on the upper border of each kidney, two in number, roughly triangular in shape. It has got outer cortex and inner medulla. The adrenal cortex serves glucose or carbohydrate metabolism, mineral metabolism and controls sex function.

Anatomy : The adrenal gland is invested by a bit of thick fibrobus capsule which is composed of connective tissue, alveolar tissue and muscle fibres. The glands are larger in women than in male. The total weight of the gland becomes 10 gms. in adult, two in number, roughly triangular in shape and lie on the upper pole of each kidney. The mammalian adrenal gland consists of two parts, which though closely associated anatomically have separate in origin, structurally different and functionally independent. The outer part of the gland is known as cortex which is firm in consistency and yellow in appearance.

Development : The mesodermel cell layer gives rise to the formation of adrenal cortex after covering neural ectoderm.

Histology : The cells of the adrenal cortex are polyhedral in shape with well defined nuclei, golgi apparatus, typical mitochondria and with high lipid content in their protoplasm. The cortical part is arranged into three zones from outside inwards :

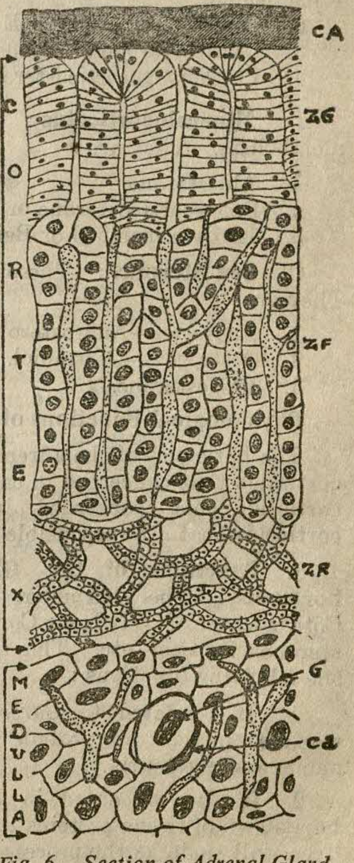


Fig. 6. Section of Adrenal Gland.
CA—Capsule, ZG—Zona Glomerulosa, ZF—Zona Fasciculata, ZR—Zona Reticularis, G—Ganglion cell, Ca—Capsule Cell.

(a) **Zona Glomerulosa** (Outer) : It is the outer layer of the cortex situated immediately beneath the fibrous capsule and the columnar cells lie with their long axis parallel to the surface. Their cytoplasm contains acidophil granules. The columnar cells are comparatively small and thickly set. These cells manufacture *aldosterone.*

(b) **Zona Fasciculata** (Middle) : It the broadest leyer with proportionally larger cells containing brownish-yellow pigment granules. This layer consists of columnar cells and lie vertical to the surface. The cells contain much lipoid material known as liposomes, few mitochondria and acidophil granules in their cytoplasm. The cells are arranged in radiating columns and perpendicular to the surface. This layer is very rich in cholesterol and vitamin C. This layer secretes *corticosterone* and *hydrocortisone.*

(c) **Zona Reticularis** (Inner) : This layer is in contact with the medulla and consists of cells that are interblocked with each other to form a reticular arrangement leaving wide blood spaces known as sinusoids lined by reticulo-endothelial cells. This layer secretes *sexocorticoids* and producing sex-hormones.

Active Principle : The sterol compounds of adrenal cortex can be divided into three groups :

A. **Glucocorticoids** : These are concerned with carbohydrate or glucose metabolism. They are :

1. 17-Hydroxy corticosterone or Cortisol or Kendall F compound.
2. Cortisone or Kendall E compound.
3. Corticosterone or Kendall B compound.
4. 11-Dehydrocorticosterone or Kendall A compound.

B. **Mineralocorticoids** : These are concerned with mineral metabolism. They are :

1. Aldosterone.
2. Deoxycorticosterone or Deoxycortone.
3. 11-Deoxycortisol or Reichstein S compound.

C. **Sex Steroids** : These are concerned with sex functions. They are :

1. Androgen—Androsterone.
2. Oestrogen—Oestradiol.
3. Progesterone.

Physiological Functions of Adrenal Cortex :

The hormones of the adrenal cortex are grouped into glucocorticoids that concerned in carbohydrate metabolism, mineralocorticoids that concerned in mineral metabolism and sexocorticoids that are responsible for sex functions.

I. **Functions of the Gluco-corticoid or Oxy-corticoid hormones** : The hormones are Corticosterone, 11-Dehydro-Coticosterone, 11-Hydroxy Corticosterone, 17-Hydroxy corticosterone, Cortisol etc. The gluco-corticoid hormones perform the following functions :

1. It is related to *Carbohydrate metabolism.* It increases neoglucogenesis from protein in liver and produces hyperglyaemia and glycosuria.

2. It is concerned in *Protein metabolism.* It stimulats breakdown of tissue proteins to amino-acids which will go to the liver, will undergo the process of deamination.

3. It plays an essential part in the *Metabolism of lipoids* and thereby mobilises depot fat forming ketone bodies in the liver.

4. It controls *Calcium metabolism.* Injection of this hormone will cause rapid withdrawal of calcium from the bone leading to a condition known as osteoporosis.

5. It is concerned on *Lymphocyte and Eosinophil count.*

6. The cortisol and cortisone hormones relieve *Muscular weakness.*

II. **Functions of the Mineralo-corticoid hormones** : The hormones are the desoxycorticosterone, aldosterone and deoxy-corticoid.

(a) *Functions of the Desxoycorticoid* : (1) This hormone regulates the mineral metabolism and water metabolism. This hormone helps in the reabsorption of sodium from the kidney tubules and excretion of potassium through the kidney. (2) The hormone also regulates the cellular mineral metabolism.

(b) *Functions of Aldosterone* : It regulates the electrolyte metabolism but its action is much more effective than the des-oxycorticoid.

III. **Functions of the Sexo-corticoid hormones** : The hormones are Androgens, Oestrogens and Progesterone. The tumours of the adrenal cortex lead to : (1) The precocious development of the body and particularly of the sex glands in male children. (2) The precocious or pre-mature sexual development in female children. (3) The reversion to the secondary sexual characters of opposite sex in adult females. (4) Occasional feminization may occur. Oestrogens may be present in the urine.

Q. 14. Describe the manifestations of hypofunction and hyperfunction of Supra-renal (Adrenal) Cortex.

The supra-renal cortex liberates three groups of hormones. They are gluco-corticoids, mineralo-corticoids and sexo-corticoids. Due to excess or lack of these groups of hormones, the different manifestations produced which are discussed below :

I. **Hypo-activity of Adrenal cortex** : Due to less secretion of gluco-corticoid and mineralo-corticoid hormones from the suprarenal cortex, *Addison's disease* is produced. It is characterised by morphological, physiological, psychological and sexological features.

(a) **Morphological Features** : (1) There will be pigmentation or bronzing of the skin and mucous membrane due to increased deposition of melanin in the Malpighian layer of skin. (2) There will be muscular weakness and easy fatigue.

(b) **Physiological Features** : (1) There will be gastro-intestinal troubles, loss of appetite, hypochlorohydria, vomiting and nausea. (2) There will be fall of blood pressure and reduced circulation rate. (3) Complex changes in the general metabolism, low metabolic rate, sub-normal temperature and loss of weight. (4) There will be less growth of tissue due to less synthesis of tissue protein. (5) The body is susceptible to infection and to mild degree of stress and strain. (6) The large amount of water will be excreted out with urine and as a result blood volume will be diminished. (7) Hypoglyycaemia may occur and it will be the immediate cause of death.

(*c*) **Psychological Features** : There will be diminished mental process, slowness of thought and sluggish movement.

(*d*) **Sexological Features** : There will be depression of sexual function. The primary and secondary sexual characters are ill developed.

II. **Hyper-activity of Adrenal Cortex** : The increased secretion of adrenal cortex produces Cushing's syndrome, Adrenogenital syndrome and Aldosteronism

A. Cushing's Syndrome : It is a disease characterised by a collection of symptoms caused due to increased secretion of cortico-metabolic hormones by the hyperactivity of the adrenal cortex. It is characterised by morphological, physiological, psychological and sexological features.

(*a*) **Morphological Features** : (1) There is wasting and weakness of the skeletal muscles of the limbs due to increased baeakdown of the muscle proteins to amino-acids and the low level of potassium. (2) There is excessive deposition of fat over the supra-condylar region and usually of characteristic distribution. (3) The skin is thin with purplish striations. There is hirsutism i. e. abnormal hairiness of the face, chest and abdomen in male. In females, masculinisation with growth of beard, moustache, etc. (4) Increased mobilisation of calcium from the bone producing osteoporosis due to excessive withdrawal of calcium salts and loss of protein matrix.

(*b*) **Physiological Features** : (1) There are signs of diabetes mellitus of varying grades of severity. The hyperglycaemia is caused due to the stimulation of neoglucogenesis and inhibition of oxidation of glucose in tissue. (2) Blood sodium level will be increased, alkalosis may result owing to an increase in sodium bicarbonate and blood potassium level will be diminished. (3) Hypertension and oedema of the body are common. (4) The oxycorticoid will cause increased mobilisation of depot fat and the mobilised fat will be redistributed to some other place of the body. (5) There are changes in the circulating blood cells. The eosinophil and lymphocyte count in the blood will be diminished. (6) There is increased destruction of tissue protein and more excretion of nitrogen in the form of urea. There will be negative nitrogen balance. (7) There will be rise of blood volume, increased cardiac output and rise of blood pressure.

(c) **Psychological Features** : There will be mental derangement which will cause diminished mental process.

(*d*) **Sexological Features** : There will be impotency with atrophy of testis and other signs of hypogonadism in the male and amenorrhoea and sterility in the female.

B. Adrenogenital Syndrome : It is a disease characterised by a collection of symptoms caused due to increased secretion of corticosexual hormones by the hyperactivity of the adrenal cortex. It may be adrenal virilism in female and Adrenal feminization in male.

(1) **Adrenal Virilism** : The females will be converted into male due to the increased secretion of male sex hormone from Zona reticularis. The general appearance, body, face and voice become of male type. Beard and moustache grow and there will be growth of hairs all over the body surface. Menstruation stops, ovaries and uterus degenerate and clitoris enlarges.

(2) **Adrenal Feminization** : The males will be converted into females due to the increased secretion of the female sex hormones from Zona reticularis. The general appearance, body, face, voice and stature become of feminine type. Beard and moustache are fallen off and the hairs all over the body become scanty. The penis become ill-developed and there will be degeneration of the testis and secondary male sex organs.

C. **Aldosteronism** : It is caused due to excess secretion of aldosterone by the hyperactivity of the adrenal cortex. It may be primary and secondary.

(*a*) *Primary Aldosteronism* : There will be intermittent muscular pains, cramps, weakness and raised blood sodium levels and alkalosis. There is no oedema of the body.

(*b*) *Secondary Aldosteronism.* It is characterised by cardiac failure, nephrosis, eclampsia and cirrhosis of the liver with ascites.

Q. 15. Describe the structure, active principle and physiological actions of Adrenal Medulla.

The supra-renal or adrenal gland is situated on the upper border of each kidney. It has got two parts namely outer cortex and inner medulla.

Structure : (Fig. 6.) The medulla is the central part of the adrenal gland. It is made up of scattered, irregularly disposed polyhedral cells or sometimes neurogleal cells richly supplied with blood vessels and is controlled by sympathetic nervous system. They are supported by an elastic tissue network. The medullary cells are closely packed polyhedral cells containing chromaffin granules.

Development : The adrenal medulla is developed from neural ectoderm and chromaffin tissue from which the sympathetic ganglia develop.

Active Principle : The adrenal medulla liberates adrenaline and nor-adrenaline. The adrenaline is a di-hydroxyphenyl derivative of hydroxy-ethyl-methylamine. The adrenal medullary hormones are produced from adrenal medulla as : The chromaffin cells of the supra-renal medulla will synthesise the active principles of the gland. The cells will take the amino-acid Tyrosine from the blood by the action of Tyrosinase and forms Di-hydroxy-phenyl alanine (DOPA) which after the activation of DOPA decarboxylase forms Dihydroxy-phenylethalmine or Dopamine. It produces nor-adrenaline (18%) after oxidation and then adrenaline (82%) after methylation.

Physiological Actions Or Functions of Adrenal Medulla (Adrenaline) : The adrenal medulla liberates adrenaline and nor-adrenaline which act on different tissues and systems of the body that are briefly summarised below :

I. **On Eye** : (1) Secretion of tear from lacrimal gland. (2) Dilatation of the pupil due to stimulation of dilator pupillae. (3) Retraction of eyelids due to contraction of tarsal muscles. (4) Protrusion of the eyeball due to contraction of the muscles of Muller.

II. **On Cardio-Vascular System** :

(a) **On Blood** : (1) There will be increased count of red blood cells in the peripheral blood. (2) The eosinophil count in the blood will be diminished. (3) The hormone hastens the blood coagulation by producing constriction of the blood vessels and by liberating more Thromboplastin from distintegrated platelets.

(b) **On Heart** : (1) Increased force and frequency of the heart. (2) Increased cardiac output and rise of blood pressure. (3) Dilatation of the coronary vessels.

(c) **On Blood Vessels** : Adrenaline will cause constriction of all the blood vessels of the body with the exception of coronary vessels and blood vessels of the skeletal muscles which will be dilated.

III. **On Respiratory System** :

(a) **On Bronchial Musculature** : The hormone will cause relaxation of the bronchial musculature and so it is used in bronchial asthma.

(b) **On Respiration** : (1) Injection of adrenaline will cause temporary stoppage of breathing due to the rise of blood pressure and it is known as *Adrenaline apnoea.* (2) It facilitates pulmonary ventilation by relaxation of the bronchi.

IV. **On Gastro-Intestinal System** :

(a) **On Salivary Gland** : Inhibition of the secretion of the digestive glands but it will stimulate the secretion of the salivary gland.

(b) **Stomach and Intestine** : This hormone inhibits the digestive glands and there will be no secretion of digestive juices. The hormone inhibits the peristaltic movements of stomach and intestine.

(c) **On Liver** : The hormone stimulates the process of glycogenolysis and thereby liver glycogen is converted into glucose which will circulate in the blood to produce hyperglycaemia and glycosuria.

(d) **On Gall Bladder** : The hormone produces relaxation of the plain muscles of gall bladder with constriction of sphincter of Oddi.

V. **On Spleen** : The hormone produces contraction of the plain muscles lining the trabeculae of the spleen and the stored blood comes out of the spleen and circulates in the blood stream.

VI. **On Excretory System** :

(a) **On Kidney** : The small dose of adrenaline produces constriction of the efferent renal arterioles and as a result, urinary output is increased. Large dose of adrenaline produces constriction of both afferent and efferent renal arterioles, filtration through the glomerulus is greatly diminished and urinary output is much reduced.

(b) **On Urinary Bladder** : The hormone produces relaxation of the detrusor muscles of the urinary bladder with the constriction of the internal urethral sphincter.

(c) **On Skin** : Adrenaline will cause contraction of the arrector pili muscles and as a result there will be erection of the hairs.

VII. **On Uterus** : Adrenaline in some animals causes relaxation of both pregnant and non-pregnant uterus but in higher animals specially in human beings, it causes relaxation of the non-pregnant uterus.

VIII. **On Metabolism** : (1) Increased basal metabolic rate by stimulating cellular metabolism. (2) It mobilises liver glycogen and provides sugar for the active tissues. (3) The adrenaline stimulates the glycogenolysis. The blood sugar level will rise and there may be glycosuria when the blood sugar level exceeds the renal threshold value of glucose.

IX. **On Skeletal Muscles** : (1) The excitability and contractility of the muscle tissue are raised. (2) The muscular fatigue will be delayed. (3) The muscle glycogen is converted into lactic acid which is carried to the blood stream.

X. **On Spinal Cord** : Large dose of adrenaline has got direct depressant action on the spinal cord and muscle tone and the reflexes will be diminished.

XI. **On Endocrine Glands** : The adrenaline will stimulate anterior pituitary to secrete more ACTH. The ACTH will then stimulate more cortical hormones after stimulating the suprarenal cortex.

Q. 16. Discuss the role of various endocrine glands on Carbohydrate Metabolism.

The regulation of carbohydrate metabolism is acheived through the endocrine system and a number of different hormones are known to be concerned in this regulation. These include Insulin and glucagon : the hormones of the Islets of Langerhans of Pancreas, adrenaline produced by the adrenal medulla : the hormones of the adrenal cortex, thyroid gland, gonad and anterior lobe of the pituitary. Many details concerning the regulation of carbohydrate metabolism are still unknown. The account given here is therefore of necessity an oversimplified one.

I. Role of Islets of Langerhans :

A. Influence of Insulin : The hormone insulin controls the storage and utilisation of sugar by the tissues, by the following ways : (1) Insulin facilitates the transference of sugar from the peripheral blood to the peripheral tissues. (2) It accelerates the conversion of glucose to glycogen both in muscles and the liver and helps in storage of glycogen there. (3) It can inhibit the formation of glucose from aminoacids and thereby prevents neoglucogenesis by keeping the diabetogenic hormone of the anterior pituitary in check. (4) It can convert glucose into fat. (5) It increases oxidation of glucose by the tissues and thereby combustion of sugar is increased. (6) It helps the tissues to burn sugar and utilise it as a source of heat and energy.

B. Influence of Glucagon or Hyperglycaemic glycogenolytic factor or H-G factor : The α-cells of the pancreatic islets produce a water-soluble hyperglycaemic glycogenolytic factor which regulates carbohydrate metabolism by stimulating the process of glycogenolysis. Injection of this hormone may therefore produce hypeglycaemia which may lead to glycosuria.

II. Role of Anterior Pituitary :

A. Influence of Diabetogenic hormone : This hormone plays an important role in the regulation of carbohydrate metabolism. This hormone stimulates the process of glycogenolysis and stimulates the process of neoglucogenesis and this hormone also inhibits the oxidation of glucose in the tissue by inhibiting phosphorylase enzyme system.

B. Influence of Growth hormone : This hormone helps, to increase the rate of growth of all growing cells of the body and thereby the rate of cellular mitosis is increased.

C. Influence of Thyrotrophic hormone : This hormone plays an important role in carbohydrate metabolism. It produces glycogenolysis, hyperglycaemia and glycosuria.

III. Role of Posterior Pituitary : This gland plays an important role in the metabolism of carbohydrate by mobilising liver glycogen with resultant transient hyperglycaemia and glycosuria. It antagonises the action of Insulin.

IV. **Role of Thyroid Gland** : Thyroid gland liberates Thyroxine that stimulates the process of glycogenolysis and also stimulates the process of neoglucogenesis. In hyperthyroidism, the blood sugar level will be high and in hypothyrodism, the sugar level will be low.

V. **Role of Adrenal Medu e** : This gland produces adrenaline and nor-adrenaline which rais the blood sugar level by stimulating glycogenolysis. Adrenaline stimulates glycogenolysis in both liver and muscle.

VI. **Role of Gonad** : It plays an important role in carbohydrate metabolism in old age. The hypoactive gonad fail to inhibit the anterior pituitary which then works unopposed and produces excess diabetogenic hormone.

Q 17. Write Short Notes On :

(1) **Adreno-Corticotrophic hormone (A.C.T.H.)** : It is one of the indirect hormone, secreted from the anterior pituitary and acts upon adrenal cortex serving the function of carbohydrate and mineral metabolism and regulates sex functions. **Formation** : The adreno-corticotrophic hormone is liberated from the anterior pituitary gland and acts upon adrenal cortex which secretes glucocorticoid, mineralo-corticoid and sexocorticoid hormones. **Functions** : (i) This hormone controls the size and activity of the adrenal cortex and regulates the secretion of glucocorticoid, mineralo-corticoid and sexocorticoid hormones. (ii) The gluco-corticoid hormone controls carbohydrate metabolism and regulates normal blood sugar level mainly but it is also concerned with protein, lipide and calcium metabolism. (iii) The mineralo-corticoid hormone controls mineral and water metabolism and also regulates the cellular mineral metabolism. (iv) The sexocorticoid hormone regulates the development of primary sexual organs and secondary sexual characters and controls sex functions.

(2) **Anti-Thyroid Durgs** : The anti-thyroid drugs are those drugs which do not help in the synthesis of Thyroxine formation from the Thyroid gland. **Name of Antithyroid durgs** : The anti-thyroid drugs are the Thyocyanates, Thiourea, Thiouracil, Sulphaguanidine, Para-amino-Benzoic acid (P.A.B.A.) and Radio-active Iodine. **Mode of Actions** : The mode of action of anti-thyroid drugs are the following : (i) The drugs like *Thyocyanates* may prevent the concentration of iodine within the cubical epithelial cells of the thyroid gland or may prevent the liberation of free iodine from the inorganic iodides. (ii) The drugs like *Thiourea* and *Thiouracil* may prevent the conjugation of iodine with the amino-acid Tyrosine to give rise to di-iodotyrosine. (iii) The drugs like *Sulphaguanidine* and *P. A. B. A.* may

prevent the conjugation of two molecules of Di-iodotyrosine to give rise to thyroxine. (iv) The drugs like *Radio-active Iodine* may destroy the cubical epithelial cells of the Thyroid gland and thereby there will be no formation of Thyroxine.

(3) **Anti-diuretic hormone** (**A. D. H.**) : The anti-diuretic hormone is liberated from the pars nervosa of posterior lobe of the pituitary gland. The hormone helps in the reabsorption of water from the distal kidney tubules and thereby regulates the urinary output and the water balance of the body. **Mechanism of Actions** : (i) 170 litres of water are being filtered through the glomerulus into the Bowman's capsule in 24 hours of which 168'5 litres are reabsorbed back into the blood from the kidney tubules to maintain the water balance of the body. Therefore the normal urinary output is 1'5 litres or 1500 ml. (ii) The secretion of A.D.H. by the posterior pituitary gland is under the influence of blood crystalloid osmotic pressure. When the blood osmotic pressure is high there will be stimulation of the osmo-receptors present near the supra-optic nuclei which will stimulate the posterior pituitary gland through supra-optico-hypophyseal tract to liberate more A.D.H. and as a result there will be more reabsorption of water from the distal kidney tubules and urinary output will be diminished. (iii) The hormone reduces chloride absorption and increases chloride loss. (iv) It causes contraction of all the plain muscles of the body excepting those of heart and uterus.

(4) **Oxytocin** (Pitocin) : The oxytocin hormone is liberated from the pars nervosa of the posterior lobe of pituitary gland which kicks the baby from the mother's womb and helps in the process of parturition. **Chemistry** : This hormone is polypeptide in nature and isolated almost in pure from. It is white or creamy amorphous powder and molecular weight being 600 to 2000. It contains a number of amino-acid like tyrosine, cystine, arginine, leucine and tryptophan. **Mode of Actions** : This hormone causes contraction of the plane muscles of uterus and the mammary gland. (i) **On Uterus** : It causes contraction of the uterus, during the later month of pregnancy because in early and middle part of pregnancy, high concentration of progesterone in the blood will inhibit the action of oxytocin on uterine musculature. Towards the later part of pregnancy, placenta and corpus luteum do not secrete any progesterone, progesterone level in the blood is diminished and oxytocin causes contraction to the uterus to expel the foetus and placenta from the uterus. (ii) **On Mammary Gland** : The hormone oxytocin produces contraction of the plane muscle lining the alveoli of mammary gland and thereby helps in the expulsion of milk from the mammary gland to the supra-optic nuclei which then though the supra-optico-hypophyseal tract will cause more liberation of oxytocin and there will be more expulsion of milk from the

mammary gland. (iii) **On Carbohydrate Metabolism** : This hormone produces hyperglycaemia in large doses specially in dogs which is concerned in carbohydrate metabolism.

(5) **Chorionic or Placental Gonadotrophin :** It is one of the gonadotrophic hormone liberated from Chorion or Placenta of female pegnant uterus. **Source** : The chorionic gonadotrophins are produced by the placenta and have been obtained from : (i) Urine and blood of pregnant women. (ii) Blood of pregnant mares. **Chemistry** : The chorionic gonadotrophin has been purified and crystallised. The crystalline substance has an activity equivalent to 6,000 or 8,000 units per milligram. **Effects** The gonadotrophins of placental origin have been found in the urine and blood of pregnant woman and the serum of pregnant mares. (*a*) *Urine and blood of pregnant women* : It is found in the urine of women who have aborted while the placenta is retained in the uterus. It is eliminated in large quantities when there is a tumour of placental origin like hydatiform mole or chorioepithelioma and in certain cases of tumour of the testicle. It has a follicle stimulating effect and a very strong luteinizing effect. It is also found in the urine and blood of pregnant woman shortly after the nidation of the embryo. Its maximum concentration in the urine occurs around the thirtieth day of pregnancy or 50 to 60 days after the last menstruation. (b) *Serum of pregnant mares* : The serum of pregnant mares has a very active gonadotrophin which is produced by special glandular structures of the placenta known as endometrial cups. It is protein in nature with great molecular weight and therefore it does not pass into the urine. It reaches its highest concentration between the fiftieth and eightieth day of pregnancy and then gradually diminishes and is not found again for the rest of the 330 to 350 days of pregnancy. It provokes follicullar growth and luteinization. **International Unit** : The international unit of chorionic gonadotrophin is the specific activity of 0·1 mm. of the international standard gonadotrophin. The international unit of pregnant mare gonadotrophin is the specific activity of 0·25 mg. of the international standard.

(6) **Lactogenic Hormone** or **Prolactin** or **Mammotrophic hormone** (**MH**) : It is a milk secreting hormone secreted from the anterior pituitary gland. **Formation :** This hormone is secreted by the eosinophil cells of the anterior pituitary gland. **Chemistry** : It is a crystalline protein, isolated in pure form and contains tyrosine, tryptophan, cystine, methionine, arginine and sulphur. The molecular weight becomes about 25,000. The free amino-groups are essential for its activity. **Mode of Actions** : (1) It stimulates slightly the proliferation of the glandular elements of the mammary glands during pregnancy. (2) It induces the secretory changes in the breast leading to initial growth and development of the mammary glands during

pregnancy. (3) It initiates, regulates and maintains the secretion and expulsion of milk and may be responsible for the suppression of gonadotropic activity of the anterior pituitary gland.

(7) **Thyroxine** : It is one of the hormone secreted from the thyroid gland. **Chemistry** : Chemically, thyroxine is Para-hydroxy-phenyl ether of Tyrosine with four molecules of Iodine. **Formation and Synthesis :** Thyroid gland manufactures thyroxine from inorganic iodide and tyrosine. This inorganic iodide will liberate free iodine with the help of peroxidase enzyme. The thyroid gland will also take amino-acid tyrosine from the blood which will combine with iodine to form 3-mono-iodotyrosine and 3 : 5—diiodotyrosine. Two molecules of di-iodotyrosine combine together to form Thyroxine and alanine is eliminated. **Mode of Actions** : (1) Thyroxine increases energy and oxygen consumption of tissues. (2) It increases carbohydrate metabolism, helps in protein metabolism and promotes calcium and phosphorus metabolism. (3) It increases excretion of nitrogen and creatine through the kidney. (4) It promotes growth of the body of an individual. (5) It acts directly on the heart and accelerates the rate of the heart beat.

(8) **Islets of Langerhans :** These are isolated cells situated in the central part of the pancreas and discovered by Langerhans. **Structures** : The islets cells are small irregular collections of epithelial cells with no ducts and found scattered between the alveoli of the pancreas. The cells are more or less polyhedral in shape. The islets cells are of four types which are known as α, β, γ and δ cells. **Active Principle** : The islets cells secrete a number of hormones. The alpha cells liberate *glucagon* and *lipocaic hormones*. The beta cells liberate *insulin* and the gamma and delta cells act as mother cells. **Functions :** (1) The Glucagon hormone increases blood sugar level producing hyperglycaemia which will lead to glycosuria when the blood sugar level becomes more than 180 mg. per 100 ml. of blood. (2) The Lipocaic hormone prevents fatty degeneration of the liver. (3) The Insulin hormone decreases the increased blood sugar level. It regulates carbohydrate metabolism through glycogen metabolism, combustion of glucose and neoglucogenesis. It stimulates lipogenesis and thereby fat metabolism is controlled. It stimulates the synthesis of tissue protein and thereby helps in the growth of the tissues.

(9) **Glucagon** : It is a hyperglycaemic factor, secreted by the alpha-cells of the islets of Langerhans. This hormone is also secreted in increased amounts during muscular activity. **Chemistry** : It is a polypeptide hormone with twentynine amino-acids having molecular weight of 3,485. **Mode of Actions** : (i) Glucagon causes glycogenolysis in the liver by activating inactive phosphorylase enzyme and thus produces

hyperglycaemia. (ii) It stimulates the breakdown of liver glycogen into glucose. The injection of glucagon will therefore produces hyperglycaemia which will lead to glycosuria when the blood sugar level becomes more than 180 mg. per 100 ml. of blood. (iii) Glucagon also increases the breakdown of amino-acids and increases neoglucogenesis from the deaminated part of amino-acid.

(10) **Acetyl Choline** : It is a chemical agent, liberated from the parasympathetic nerves and nerve endings and serves the function of transmission of nerve impulse through the somatic and autonomic synapses. **Formation** : Acetyl choline is formed in different regions of the body such as : (i) At all parasympathetic nerves and nerve endings. (ii) The sympathetic nerve endings that supply the sweat glands and arrector pili muscle. (iii) At all the synapses that are present in the autonomic and somatic nervous system. **Chemistry** : Acetyl choline is the acetyl ester of choline. It is produced in the body by the action of acetyl CoA and choline in presence of choline acetylase enzyme. The choline is the derivative of ammonium hydroxide whose hydrogen atoms attached to the nitrogen, are replaced by three methyl groups and one hydroxy-ethyl group. **Mode of Actions** : (i) It has got direct peripheral action upon certain blood vessels and certain organs like intestine and uterus etc. (ii) It has possessed parasympatho-mimetic action on all tissues supplied by cholinergic fibres. (iii) It performs nicotine-like action on all the autonomic ganglia. **Functions** : (i) It helps in the development of end-plate potential. (ii) It exerts parasympatho-mimetic action on all the tissue supplied by cholenergic autonomic fibres. (iii) It plays an important role in the transmission of nerve impulses through the somatic and autonomic synapses. (iv) It exerts direct peripheral action on certain tissues and organs like uterus and intestine, etc.

(11) **Nor-Adrenaline** : It is one of the hormone of adrenal medulla discovered by *Goldenburg* and his associates and is supposed to be the actual sympathetic transmitter that is produced at the endings of the adrenergic fibres. **Formation** : The nor-adrenaline or nor-epinephrine is one type of hormone secreted from the adrenal medulla. **Chemistry** : Adrenaline is a tyrosine derivative which is oxidised into dihydroxy-phenylalanine (DOPA). It undergoes decraboxylation and forms dopamine which after oxidation transforms into nor-adrenaline. **Mode of Actions** : The mode of action of nor-adrenaline is more closely sympathomimetic than adrenaline. Its actions upon certain organs and structures are as follows : (i) *On heart* : There will be slowing of the heart beat and the blood pressure is raised. (ii) *On Blood vessels* : In produces constriction of all the blood vessels irrespective of coronary vessels

and blood vessels of skeletal muscles. (iii) *On Carbohydrate metabolism* : The break down of liver glycogen into glucose is minimum and there will be slight increase of blood sugar. (iv) *On Eye* : The dilatation of the pupil is very slight.

(12) **Sex hormones** : The sex hormones are those hormones which are found in the gonad such as testis in male and ovary in female. **Formation** : The sex hormones are formed from the gonad as gonadotrophins, from testis and ovary and from adrenal cortex of the supra-renal gland. **Varieties** : The sex hormones are of male type such as androgen and testosterone and of female type such as oestrogen, progesterone and relaxin hormones. **Control** : The sex hormones are controlled by F. S. H., L. H. and I. C. S. H. of the gonadotrophic hormone of the anterior pituitary, by the I. C. S. H. hormone of testis and ovary and the sexocorticoid hormones of the suprarenal cortex. **Functions** : (1) The androgen serves the functions of growth of accessory male sex organs, development of male secondary sexual characters, increasing the span of life and fertilizing power of spermatozoa, muscular development and growth of bone. (2) The oestrogen and progesterone serve the functions of development of primary sex organs and secondary sexual characters, control of pubertal changes in female and stages of menstruation, etc. (3) The relaxin hormone relaxes the pelvic ligament during pregnancy.

(13) **Differences between Adrenaline and Nor-adrenaline** :

Adrenaline	**Nor-Adrenaline**
(1) **Chemistry** : It contains additional methyl group.	(1) **Chemistry** : It contains no methyl group.
(2) **On Heart** : The force and frequency of heart beat will be increased.	(2) **On Heart** : There will be slowing of the heart beat.
(3) **On Blood Vessels** : It produces constriction of all the blood vessels with the exception of coronary vessels and blood vessels of the skeletal muscles.	(3) **On Blood Vessels** : It produces constriction of all the blood vessels irrespective of coronary vessels and blood vessels of skeletal muscles.
(4) **On Carbohydrate Metabolism** : The hormone stimulates the process of glycogenolysis i.e. it converts the liver glycogen into glucose and there is rise of blood sugar level.	(4) **On Carbohydrate Metabolism** : The breakdown of liver glycogen into glucose is minimum.
(5) **On Eye** : Adrenaline produces dilatation of the pupil and contraction of the nictitating membrane in frog is prominent.	(5) **On Eye** : The dilatation of the pupil by the hormone is very slight and the action over the nictitating membrane is practically nil.

CHAPTER
TWO

REPRODUCTIVE PHYSIOLOGY

Introduction : In reproduction, there are two mature reproductive cells known as gametes. They fuse to form a single cell known as zygote. The gametes develop in parents of different sex, male and female gamete is a sperm cell or spermatozoon and the female gamete is an egg cell or ovum. Each gamete develops gonad by a process of gametogenesis. The male gonad is known as testis and its maturation process is known as spermatogenesis while the female gonad is ovary and its maturation process is known as oogenesis. The process of fusion between the two is called fertilization and the end product is known as zygote.

The male sexual organs consist of testes, epididymis, vas deferens, seminal vesicles, ejaculatory ducts, prostate and penis. The female sexual organs include ovaries, fallopian tubes, uterus, bartholin's glands, clitoris and vagina. Out of these organs, testes and ovaries are known as primary sex organs and the remaining structures collectively called secondary sexual organs. Testis and ovary are mixed glands. Testis produces sperematozoa and liberates hormones like testosterone, androgen etc. Ovary produces ova and secretes hormones like oestrogen, progesterone and relaxin.

Q. 1. Describe the Secondary Sexual Characters of Man. How they are controlled by hormones ?

The secondary sexual characters are the newly formed additional characters which grow over the body due to the influence of the hormonic effect of the primary sexual glands like testis in male and ovary in female, during the age of 12 to 16 years i.e., on and after puberty localised both in males and in females. These characters help to distinguish male from a female species.

I. **Secondary Sexual Characters in Male :** The sexual characters in male are developed due to the infuence of testosterone and androgen hormones that are liberated from the testis. These characters are characterised by morphological, physiological, psychological and sexological changes :

(A) **Morphological Changes** : (1) Growth of hairs within the external cavity of the nose (nostril) known as nasal hairs. (2) Growth of hairs on the upper lip known as moustache. (3) Growth of hairs all over the surface of the face form beard. (4) Growth of hairs at the inner surface of the axilla (axillary region) form axillary hairs. (5) The hairs grow on the surface of the chest and abdominal region form breast hairs and the abdominal hairs. (6) The hairs grow at the circumference of the pigmented areolar region of the mammary gland. (7) The hairs grow over the pubic region form pubic hairs which are convex forwards. The hairs on the pubis extend forward the umbilicus and the anus. (8) The hairs grow at the outer margin of the anus form anal hairs. (9) The hairs grow all over the body surface form surface hairs. (10) The hairs grow on the outer rim of the auricle of exernal ear which are known as auricular hairs. (11) The muscles grow on the neck and shoulder region. (12) Development of muscles on the supra-clavicular region and gluteal region. (13) Deposition of fat over the face and abdominal region. (14) Less deposition of fat in the subcutaneous tissue. (15) The mammary glands become rudimentary in male. (16) The voice of male breaks remarkably and the individuals become well developed larynx and low toned voice. (17) The body structure becomes longer, muscular and stouter than females and assuming the "male type".

(B) **Physiological Changes** : (1) The increased heart rate causes greater cardiac output, high blood pressure and more tissue oxidation. (2) The respiratory rate becomes rapid and metabolic rate is increased. (3) The red cell count is increased. (4) The testosterone and androgen are secreted gradually. (5) Spermatogenesis starts and formation of spermatozoa from the seminiferous tubule, begins. (6) Semen formation begins and process of ejaculation starts.

(C) **Psychological Changes** : (1) The affinity towards opposite sex is localised. (2) The male individuals become initiative, aggressiveness, abstract thinking, idealism and interest in social problems.

(D) **Sexological Changes**. (1) The primary and accessory sexual structures like epididymis, vas deferens, urethra and penis with the prostate, seminal vesicles and Cowper's glands are well developed. (2) There will be appearance of sexual desire towards opposite sex.

II. **Secondary Sexual Characters in Female :** The secondary sexual characters in female are developed due to the influence and activation of progesterone and oestrogen which are liberated from the ovary. These characters are characterised by morphological, physiological, psychological and sexological changes.

(A) **Morphological Changes** : (1) The hairs grow within the nasal aperture and axillary region. (2) The disposition of hairs all over the body are fine and scarce. (3) The hairs on the pubis are limited by horizontal line, triangular in shape and concave forwards. (4) There is no beard or moustache, hairs on the head are longer and without tendency to baldness.

(5) The mammary gland is well-developed along with huge deposition of sub-cutaneous fat in that area. (6) The pelvis is broad and transverse diameter is greatest at the hips. (7) There is more subcutaneous fat deposition all over the body specially in neck, abdomen, pelvis and supra-clavicular region. (8) The skin becomes soft and thin. (9) The larynx is less developed with high-toned voice. (10) The body stature becomes lower than males.

(B) **Physiological Changes**: The heart rate, cardiac output, tissue oxidation and blood pressure are increased. (2) The basal metabolic rate is lowered. (3) The red cell count is decreased. (4) The oestrogen and progesterone hormone are liberated in the blood from the ovary. (5) Ovary matures, ovulation occurs and menstruation appears.

(C) **Psysiological Changes**: (1) The greater affinity towards opposite sex is localised. (2) The female individuals become more highly developed emotivity and affections, maternal and family sentiments with practical outlook.

(D) **Sexological Changes**: (1) The primary and accessory sexual structures like fallopian tubes, uterus, vagina, vulva, clitoris and the glands in the mucosae of the famale genital tract are well developed. (2) There will be appearance of sexual desire towards opposite sex.

Hormonal Control of Secondary Sexual Characters:

The hormones like androgen, testosterone etc. stimulate the development and maintenance of feminine sexual characters are known as oestrogen, progesterone and relaxin.

(a) **In Male**: (1) The growth of hairs is controlled by the gonadotrophic hormone of anterior pituitary, sexocorticoid hormones of adrenal cortex and testosterone. (2) The development of muscles are controlled by the somatotrophin or growth hormone of anterior pituitary. (3) All the physological characters are controlled by the metabolic hormones of anterior pituitary and vasopressin of posterior pituitary. (4) The development of psychological and sexological characters in male are controlled by the androgen and testosterone hormone of the testis of the male individual.

(b) **In Female**: The growth of hairs is controlled by the gonadotrophic hormone of anterior pituitary, sexocorticoid hormone of adrenal cortex, oestrogen and progesterone of ovary and placenta. (2) The development of muscles are controlled by the somatotrophin of anterior pituitary. (3) The development of mammary gland is controlled by the oestrogen and progesterone of placenta and ovary and prolactin of anterior pituitary. (4) All the physiological secondary sexual characters are controlled by the metabolic hormone of anterior pituitary and vasopressin of posterior pituitary. (5) The development of psychological and sexological characters are controlled by the oestrogen and progesterone of ovary and adrenal cortex.

Q. 2. Describe the situation, structure and functions of Testis.

Testis, the male redroductive organ, is situated one on each side within the scrotum. It is responsible for growth, maturation and development of sperm and maintains all the primary and secondary sexual characters by the action of testicular hormone known as testosterone.

Situation : It is attached to the region of the sacro-iliac joint, then it passes to the deep and superficial inguinal rings and finally to the bottom of the scrotum.

Anatomy : The testis, the reproductive organ in male are suspended in the scrotum by the spermatic cords. The average dimensions of the testis becomes 4×2·5×3 Cm. They are flat oval bodies which is covered by a tough, fibrous capsule, tunica albugenia from which trabeculaedescend and divide the gland into a number of pyramidal tubules. The tubules are filled up by convoluted siminiferous tubules, each about 500 m.m. long. A number of tubules unite to form straight tubules, which again unite to form Rete testis. They join to form vasa efferentia which combine ultimately to form the duct of epididymis. The whole epididymis consists of a single convoluted tubule and remain coiled up at the back of the testis and is continued as vas deferens. The vas deferens is joined with the seminal vesicles and form ejaculatory duct which opens into the prostatic urethra.

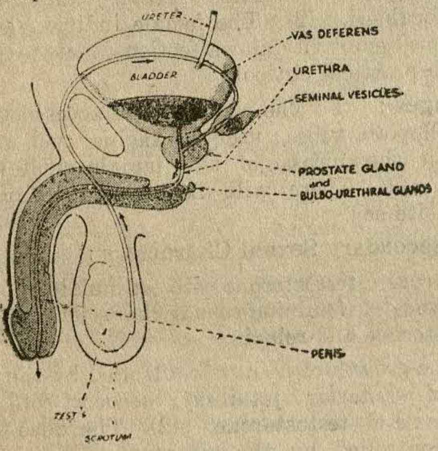


Fig. 7. Anatomical Organisations of Male Reproductive Organ.

Histology : The testis is composed of a fibrous tunica albugenia, seminiferous tubules and a male hormone liberating from the interstitial cells.

(a) **Seminiferous Tubules :** Lying within the pyramidal lobules, the seminiferous tubule consists of several layers of cells, each layer representing a particular stage of development of spermatozoa. From outside inwards the following layers of cells are : The outermost layer is *Spermatogonia* and in this layer at intervals there are some supporting cells known as *Cells of Sertoli* or *Sustentacular Cells.* It contains a spindle-shaped crystalloid near the nucleus. The Sertoli Cells are believed to perform a nutritive and supportive function towards the development of spermatozoa and the spermatids are found to be attached to them. By the activity of follicle stimulating hormone of anterior pituitary the outermost layer will be converted into *Primary Spermatocyte* which will be further converted into *Secondary Spermatocyte*. The cells of this layer will divide and will be converted into *Spermatids*. The cells of this layer by the process of modification willbe converted into *Spermatozoa*. The permatids and sperms are attached to the inner margin of the scells are alleged to be nourished by them.

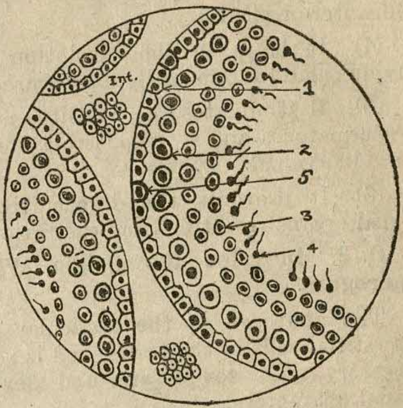


Fig. 8 Histological Structure of Testis. Int. : Interstitial Cell. 1. Spermatogonia, 2. Spermatocyte, 3. Spermatids, 4, Spermatozoa, 5, Cells of Sertoli.

(b) **Interstitial Cells** (Cells of Leydig) : These are groups of polyhedral cells with rich protoplasm and well marked nuclei, situated inside the stroma and between the seminiferous tubules. The cells contain yellow pigment lipoid granules and are arranged usually round the blood vessels. These cells are probably to be concerned in the formation of testosterone whose secretion is under the control of the pituitary gonadotrophic hormones.

Functions of Testis :

I. **Exocrine Functions** : The exocrine function of testis is spermatogenesis. In this case, sperms are developed in the seminiferous tubules with the help of Follicle stimulating hormone of anterior pituitary. The spermatogonia divides into primary and secondary spermatocytes which by reduction division form spermatids that finally matures into spermatozoa. This spermatozoa helps in the process of reproduction.

II. **Endocrine Functions** : It includes the activity of testosterone which is liberated from the interstitial cells of the testis. The main endocrine functions of the testis are :

(1) It helps in the growth and development of the accessory sexual organs of reproduction like epididymis, vas deferens, seminal vesicles and prostate.

(2) It helps in the appearance and development of secondary

sexual characters at puberty and their persistence during the rest of the life of the individual.

(3) It controls the secretion of gonadotrophic hormones from the anterior pituitary.

(4) It helps in the involution or atrophy of thymus and thymus gland is gradually disappeared.

(5) It stimulates the vitality, motility and fertilizing power of spermatozoa and is responsible for the emotional make up in male individual.

(6) It prevents the degenerative changes in the accessory sexual organs resulting from castration.

Q. 3. Describe the Origin, Varieties and Functions of Androgens.

The androgen is the testicular hormone secreted from the interstitial cells of the testis and is responsible for the growth of accessory male sex organs and development of male secondary sexual characters.

Origin (Source) : The androgen hormone is liberated from :

(1) **From Testis** : The interstitial cells of the testis secrete testosterone hormone.

(2) **From Adrenal Cortex** : The Zona reticularis layer of the adrenal cortex liberates testosterone hormone.

(3) **From Ovary** : The hormone androgen is also found in virilizing ovarian tumours.

Terminology (Varieties) : There are two types of androgen compound—Natural and Synthetic.

(a) **Natural :** The natural androgen is *Testosterone* which has been synthesized from cholesterol. There is another natural androgenic product known as *Pregnenolone* which maintains spermatogenesis in the hypophysectomized rat. The other natural products of androgens are *androsterone, deoydroandrosterone* and *dehydroepiandrosterone*. They are all found in the urine.

(b) **Synthetic** : The synthetic products of androgen are *methyl testosterone* and *testosterone propionate*. They are effective by mouth being freely absorbed and unaffected by liver.

Functions of Androgens : The functions of androgen may be summarized as follows :

(1) It helps in the growth of primary sex organs in male and helps in the development of secondary sexual characters at puberty and their persistence during the rest of the life of the individual.

(2) It helps in the growth and development of the accessory

sexual organs of reproduction like epididymis, vas deferens, seminal vesicles and prostate.

(3) It controls the secretion of gonadotrophic hormone from the anterior pituitary gland.

(4) By an action on the epididymis, androgen enhances and maintains the motility and fertilizing power of the Spermatozoa.

(5) This hormone serves as a growth-promoting action, remarkably anabolic and cause nitrogen retension and causes increased passage of amino-acids inside the cell.

(6) They act directly upon the nervous system to shape the sexual behaviour of the individual.

(7) This hormone increases the deposition of calcium salts in bone matrix resulting the increase in size and strength of bone.

Q. 4. Describe the Structure and Functions of Ovary.

Ovary, the female sex organ, two in number lying within the pelvis, serves the growth, maturation, fertilization and development of ova and maintain the normal growth and physiological functions of female sexual characters by the activation of different types of ovarian hormones known as oestrogen, progesterone and relaxin.

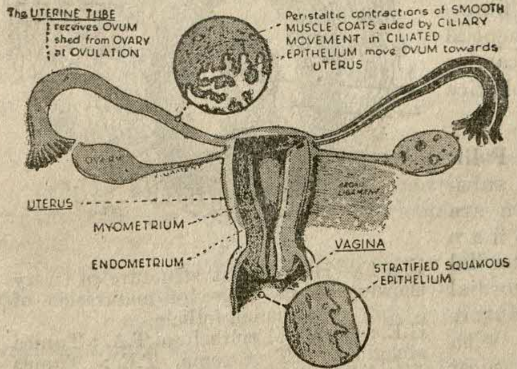


Fig. 9. Anatomical Organisation of the Female Reproductive Organ.

Situation: The ovaries are somewhat bean-shaped bodies, one on each side of the uterus, near the free end of the fallopian tube, hanging from the broad ligament by a fold of peritoneum known as mesovarium.

Development : The coelomic epithelium covering the medial part of the mesonephros becomes many layered and forms a ridge called genital ridge. From this solid cord of cells grow in form of mesonephros, called ovarian cords. These cords are cut off from their connection with the mesonephros by mesoderm which forms tunica albugenia. These cords develop into Graafian follicles.

Anatomy : The ovary is a bean shaped structure, two in number having the usual dimension of 4 × 2·5 × 1·5 cms. The ovaries are attached with the ligament of ovary to the uterus. The are covered by broad ligament and richly supplied with blood vessels and nerves.

Histology : The structural pattern of the ovary varies in childhood, puberty, pregnancy and menopause. The mature ovary has got the following structures :

(1) **Mesovarium** : The ovary is enclosed by a thin layer of peritoneal cavity known as mesovarium.

(2) **Germinal Epithelium** : The ovary is lined by a single layer of cuboidal cells known as germinal epithelium which lies below the mesovarium. It is the parent tissue from which the primitive graafian follicles develop.

(3) **Tunica Albuginia** : Just underneath the germinal epithelium there is a layer of eosinophilic collagenous connective tissue known as tunica albuginia.

(4) **Stroma** : It consists of irregularly arranged, spindle-shaped cells with a few involuntary muscle fibres and connective tissue and unstriped muscle fibres. It supports the essential ovarian tissue and carries blood vessels, lymphatics and nerves.

(5) **Primordial Follicles** : Within the substance of ovary there are immatured graafian follicles or primordial follicles. This primordial follicles contain immature ovum and loaded with lipoid material but most of them degenerate and the rest will be converted into matured graafian follicle.

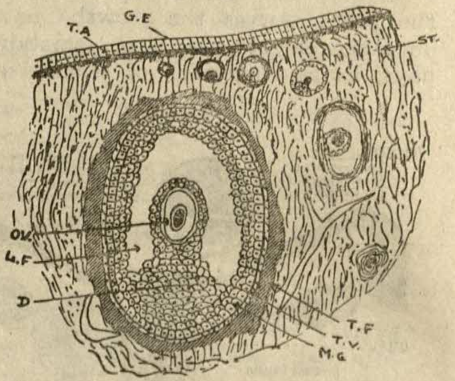


Fig. 10. Histological structure of Ovary showing various stages of maturation of Graafian follicle.
G.E. : Germinal epithelium, T.A. : Tunica albuginia, S.T. Stroma, T.E. : Tunica Fibrosa, T.V. : Tunica vasculosa, M. G : Membrana granulosa, D : Discus proligerus, L.F. : Liquor Folliculi, OV : Ovum.

(6) **Graafian Follicles** : The ovary is covered with a layer of cubical cells called germinal epithelium which are ultimately cut off from the surface. They undergo further development to form the graafian follicle. Under the influence of F.S.H. of anterior pituitary, the single layer of fibrous stroma will be converted into two distinct separate layers. The outer layer

is fibrous in character and is known as *Theca externa* or *Tunica fibrosa*. The inner layer is vascular in character and is known as *Theca interna* or *Tunica vasculosa*. By the activation of F.S.H., the single layer of primordial follicle will be converted into several layers known as *Membrana granulosa*, which secretes the important hormone known as oestrogen. The graunlosa then proliferates to form many layers of small cells. The fluid appears in these cells first as droplets which coalesce to form a cavity containing *Liquor folliculi* that nourishes and protects the ovum.

(7) **Corpus Luteum** : After the discharge of the ovum the cavity of the ruptured graafian follicle becomes filled up by yellow lipoid material known as corpus luteum. It helps in the secretion of a hormone known as *Progesterone*.

(8) **Interstitial Cells** : These are groups of polyhedral cells containing lipoid granules representing stored *Oestrogen*. They are developed from the stroma cells or from the cell of unruptured follicles.

Functions of Ovary : The ovary serves double type of functions—exocrine and endocrine.

I. **Exocrine Functions** : The exocrine function comprises the formation of ova after ovulation. They are discharged from the matured graafian follicle and unites with the sperm in the ampulla during fertilization. After union, zygote has been formed and further development takes place within the uterine bed.

II. **Endocrine Functions** ; The ovary produces *oestrogen*, *progesterone* and *relaxin* which are responsible for :

(1) It controls growth and nutrition of accessory sex organs and the appearance, development and persistence of secondary sexual characters.

(2) It is responsible for the cyclic changes of menstruation in human female and oestrous changes in lower animals.

(3) It helps in the growth and development of uterus and vagina at puberty.

(4) It is responsible for the embedding of the ovum and the development of placenta during pregnancy.

(5) It helps in the development of ducts, nipple and interstitial tissue of the mammary gland.

(6) The hormone *relaxin* increases the birth canal by softening and relaxing the pelvic ligaments during pregnancy and thus helps in partuition. It also promotes the growth of the vagina.

Q. 5. Describe the formation, structure, fate and functions of Graafian follicles.

The graafian follicles are the matured developed cuboidal cells known as germinal epithelium which is lined in the ovary.

Formation of Graafian follicles : The surface layer of the ovary is lined by cuboidal cells known as *germinal epithelium*. It sends down finger-like processes known as *genital cords*. The cords become cut off from the surface and are broken up into small islands of cells of which one cell becomes enlarged and develops into graafian follicle.

Structure of Graafian Follicle : (Fig. 10.) The single layer of fibrous stroma will convert into two distinct separate layers under the influence of F.S.H. of anterior pituitary gland. The outer layer is fibrous in character and is known as *Theca externa* or *Tunica fibrosa*. The inner layer is vascular in character and is known as *Theca interna* or *Tunica vasculosa*. The immature graafian follicles convert into primordial follicle which converts into several layers and forms *Membrana granulosa* which secretes *Oestrogen* hormone. The granulosa after proliferation forms a number of small cells which produces a cavity containing *Liquor folliculi* that nourishes and protects the ovum. The cells that surround the ovum forms a mass of *Discus proligerus*.

Fate of Graafian follicle : The fate of graafian follicles are the following : (1) Before puberty, maturation of the graafian follicle is complete and the ovum dies which is phagocytosed by the granulosa cells. (2) Before puberty and menopause, about 500 graafian follicles undergo complete maturation and ovulation takes place. (3) After ovulation, corpus luteum forms and gradually ruins. (4) After menopause, all the remaining graafian follicles degenerate and destroy.

Functions of Graafian follicles : (1) It forms matured ova after ovulation. (2) It secretes oestrogen from cropus luteum. (3) It provides a medium for the growth of corpus luteum after ovulation by the influence of F.S.H. hormone of anterior pituitary gland.

Q. 6. Describe the formation, structure, fate and functions of Corpus Luteum.

The germinal epithelium of the ovary matures into graafian follicle. By the influence of follicle stimulating hormone, graafian follicle ruptures and ovum is expelled out. The ruptured graafian follicle is soon replaced by lipoid material and forms corpus luteum which liberates *progesterone* hormone.

Formation of Corpus Luteum : After the discharge of the ovum, the cavity of the ruptured graafian follicle becomes filled up by a clot of blood. The small body formed in this way is sometimes spoken of as *Corpus haemorrhagicum*. This clot is soon replaced by a mass of cells containing a yellow lipoid material or luteal cells. These cells will secrete a hormone known as progesterone. Corpus luteum is formed on about the 13th day of menstruation and continues to grow for 5 days.

Structure of Corpus Luteum : The corpus luteum grows on the remains of the ruptured graafian follicles and possesses the following structures :

(1) The small central cavity is filled up with blood due to release of tension causing rupture of blood vessels in the tunica vasculosa.

(2) The lining membrane of the graafian follicle collapses in folded layer.

(3) The lutein cells are derived from the stratum granulosum. The cells are large, polyhedral with prominent nuclei and contain a yellow pigment known as lutein.

(4) The para-lutein cells are derived from tunica interna. They are smaller and contain lutein.

(5) It consists of delicate strands of vascular connective tissue elements of theca externa which in the centre is condensed to form a mass devoid of any cells.

Fate of Corpus Luteum : The curpus luteum persists upto 27th day of the menstrual cycle and after that it will degenerate and will be replaced by fibrous tissue. If fertilization occurs, corpus luteum will hypertrophy. The corpus luteum which can be found during menstrual cycle is known as *false corpus luteum* or *corpus luteum spurium.* The degenerated corpus luteum which is replaced by fibrous tissue is known as *corpus luteum albicans.* The hypertrophied corpus luteum which is found during pregnancy is known as *corpus luteum verum.*

Functions of Corpus Luteum : **(1)** The corpus luteum secretes oestrogen and progesterone hormones which help in the process of menstruation,puberty,pregnancy and development of secondary sexual characters in female. **(2)** It secretes relaxin hormone which helps in the softening and relaxation of the pelivic ligaments and separation of the symphysis pubis during pregnancy

Q. 7. Describe the origin, varieties and functions of Progesterone.

The progesterone is one of the ovarian hormones secreted from the corpus luteum and is responsible for gestation and many other changes in the female individual associated with pregnancy.

Origin (Source) : The progesterone hormone is secreted from :

(1) Corpus Luteum : After discharge of the ovum, the graafian follicle becomes filled up by a clot of blood which is soon replaced by luteal cells and forms corpus luteum. This corpus luteum after the influence of lutenizing hormone secretes pregesterone.

(2) **Adrenal Cortex** : It is present from the sexocorticoid hormone of adrenal cortex.

(3) **Placenta** : The human placenta also contains large quantities of progesterone which are believed to be actually manufactured by this organ.

Terminology (Varieties) : There are two types of progesterone compound—Natural and Synthetic.

(a) **Natural** : The natural progesterone in obtained from stigmasterol which is prepared from cholesterol. It may appear in the urine in pregnant women as *pregnanediol glycuronate.* The natural progesterone is a sterol derivative with a side-chain at the 17C atom.

(b) **Synthetic** : The synthetic product of progesterone is the *pregnanediol* which is physiologically inert reduction derivative of progesterone. The important members are the *Northynodril* and *Norethindrone* that inhibit ovulation process.

Functions : The functions of progesterone hormone are discussed below :

(1) It helps in the growth of primary sex organ and development of secondary sexual characters in female.

(2) It acts on the secretory phase of the menstrual cycle. Oestrogen and progesterone must act synergitically on the mucous membrane of the uterus during menstrual cycle.

(3) This hormone helps in the proliferation of alveolobular system of the mammary gland and develops breasts.

(4) It helps in the embedding of the fertilized ovum in the mucous membrane of the uterus.

(5) This hormone helps in the formation and development of placenta.

(6) It prevents the action of oxytocin on the uterine musculature and thereby helps in the growth of uterus during pregnancy process.

(7) It stops further ovulation, oestrous and menstruation during pregnancy and parturition.

(8) It inhibits the action of oxytocin on uterine musculature.

(9) The progesterone helps in the development of uterus and birth canal during pregnancy.

Q. 8. Describe the origin, distribution, varieties and functions of Oestrogen.

The oestrogen hormone is liberated from the interstitial cells of the ovary, having feminizing or oestrogenic property and can produce oestrous cycle in ovariectomized animal.

Origin (Source) and Distributions :

(1) **Ovary** : (i) The mature follicular cells, probably in theca interna is one of the chief source of the production of oestrin. (ii) The interstitial cells may be of the other source of this hormone.

(2) **Blood and Muscles** : According to *Zondek*, the sources of oestrin are in the blood, muscles and in the urine of both pregnant and non-pregnant females, in the urine of adult males, as in the testes.

(3) **Urine** : It is present in a very high concentration in the urine of pregnant women after the first two or three months.

(4) **Placenta** : The human placenta also contains large quantities of oestrogen which are believed to be actually manufactured by this organ.

(5) **Adrenal Cortex** : An oestrogen is present in the corpus luteum, in the foetal membrane, amniotic fluid, in the adrenal cortex and it has been demonostrated in a human chorionic vesicle containing an embryo of 12·5 m.m. in length.

(6) **Testes** : Oestrogens have been extracted from testes in small amounts.

Terminology (Varieties) : There are two types of oestrogen such as natural and synthetic products :

I. **Natural Oestrogens** : There are a number of natural oestrogens which are the following :

(1) **Oestrone** : It is a ketohydroxyoestrin or oestrone. It is a less potent substance. It is found in adult female urine and increases during pregnancy. It is a derived product of oestradiol and is excreted in the urine as glucuronates.

(2) **Oestriol** : It is as Trihydroxyoestrin or Oestradiol. It is transformed into oestrone by dehydration in vacuo with potassium bisulphate.

(3) **Oestradiol** : It is a third crystalline compound which was first prepared in the laboratory by the reduction of ketone group in oestrone to a hydroxyl group. It is the natural hormone secreted by the ovary.

(4) **Emmenin** : It is isolated from human placenta which is an ester of Oestriol.

(5) **Benzoate of Oestradiol** : The replacement of hydroxyl group in the 3 position in oestradiol with Benzoic acid gives as Benzoate of oestradiol or Oestradiol dipropionate and Ethenyl oestradiol.

II. **Synthetic Oestrogens** : Oestradiol have been synthesised from cholesterol. The synthetic oestrogenic compound are the following :

(1) **Glycuronide of Oestriol** : It is excreted in the urine during pregnancy when it is conjugated with glycuronic acid. It is physiologically inert but is hydrolysed.

(2) **Iso-Oestradiol :** It is a form of oestradiol which is obtained from the urine of pregnant mares.

(3) **Diethylstilbestrol** : It exhibitis an oestrogenic potency between two and three times that of oestrone.

(4) **Hexestrol** : It is chemically known as dihydroethyl stilbestrol which is suitable for clinical use and have possessed less potency.

(5) **Dienestrol** : It is suitable for clinical use and has about 60% of the activity of diethylstilbestrol.

Functions of Oestrogen : The oestrogen hormone is liberated from the interstitial cells having the following functions :

(1) It induces oestrus in immature animals or in ovariectomised animals or in normal adult animals during anoestrus.

(2) It prevents the inevitable atrophy of the accessory reproductive organs in ovariectomised animals.

(3) It is believed to be responsible for the development of secondary sexual characters and growth of the primary sex organs in immature females.

(4) It is believed to be responsible for the enormous growth of the uterus during pregnancy.

(5) It sensitises the uterine muscle to the action of pitocin and pituitarin towards the onset of labour.

(6) If, after menstruation has been abolished, a series of injection of oestrogen is given and then stopped abruptly, menstruation occurs a few days later.

(7) Oestrogen acts as a "primer" for the corpus luteum hormone (progesterone) and is apparently necessary for the maintenance of the peristance of the corpus luteum during pregnancy.

(8) The effect of oestrogen upon the nasal mucosa cause nasal swelling and reddening, nasal haemorrhage or nasal bleeding and has been useful in the treatment of Atrophic Rhinitis.

(9) It induces water retention, an increase in blood volume and the water contents of the muscles.

(10) It produces various degrees of proliferation of the ducts and occassionally of the alveoli of the breasts.

(11) It regulates the regenerative and proliferative stages of menstrual cycle.

(12) It controls the secretion of gonadotrophic hormones from the anterior pituitary, when the oestrogen level in the blood is very high and there will be inhibition of secretion of gonadotrophic hormones of antericr pituitary.

(13) Oestrogen acts as a growth hormone of the female genital tract. It promotes stratification and mucification of the vaginal epithelium and increases the size and vascularity of the cervix.

(14) Oestrogen hormone has got an effect on protein synthesis and increases the total body protein.

(15) Oestrogen causes increased deposition of fat in subcutaneous tissue and other particular regions of the body to form a typical feminine body.

Q. 9. Give an account of Menstrual Cycle in Human female.

Menstruation is a stage rehearshaling of pregnancy where Hamlet is played without the Prince of Denmark. The endometrium is the stage, the pituitary is the dramatic director, the ovary is the actress and the surface epithelium, stroma, glands and blood vessels become the dresser. Menstruation itself marks a frustration of nature—the acknowledgement of failure of fertilization. It is the cyclic bleeding due to the cyclic changes of the endometrium occuring throughout the reproductive life of female. There is a flow of blood and mucous from the uterus due to disintegration and shedding of endometrium in every 28±3 days and lasting from 4 to 5 days in each time. It occurs every month from puberty to menopause i. e., it usually starts at the age of 13 to 14 years and completely stops at the age of 45 to 50 years. It is absent before puberty and after menopause and during pregnancy and lactation.

Cyclical Changes in the Uterus : This cycle may be roughly divided into follicular (oestrogen) phase leading upto ovulation, i.e., the first 14 to 16 days and luleal (progesterone) phase for the remainder. The following changes occur in the endometrium during each menstrual cycle.

I. Regenerative Phase or Phase of Repair or Resting Phase (5th to 7th day) : It commences immediately after the stoppage of menstruation. The epithelium of the endometrium which was shed during the menstrual flow, is restored upto 1 m.m. thick and consists of ciliated columnar epithelium. The endometrial glands are small and tubular. The endometrial blood vessels are small and straight and the stroma cells are small. Its duration is 4 to 5 days.

II. Prolifeative Phase or Period of Growth (8th to 14th day): The endometrium becomes thickened upto 3 m.m. in length after proliferation. The surface epithelium becomes taller and low columnar in type. The uterine glands become greatly lengthened and tortuous and the uterus becomes highly vascular. The endometrial blood vessels become coiled and the endomerial glands become cork-screw shaped. The stroma cells are more vascular. The graafian follicle is fully matured, ovulation takes place on the 14th day and corpus luteum formation starts. The vaginal smear shows acidophil cells with small nuclei. There will be further proliferation of mammary ducts and interstitial tissue of the mammary glands. The maximum excretion of oestriol and oestrone are found in the urine.

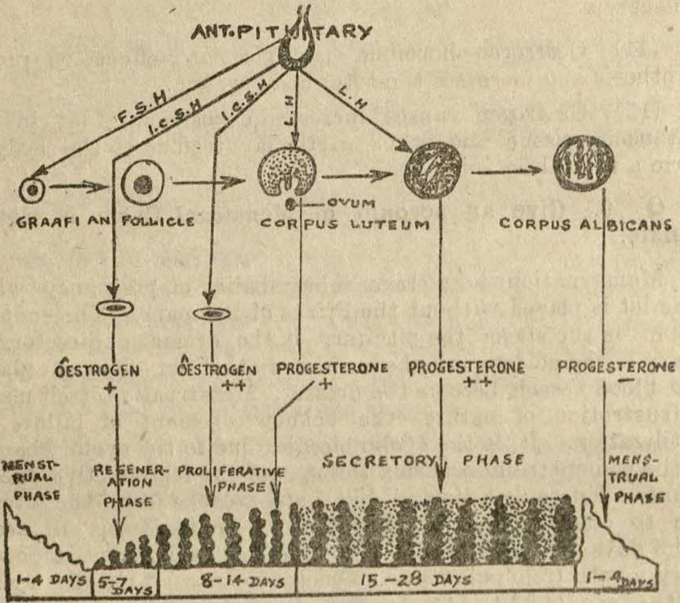


Fig. 11. Different Phases of Menstruation showing Endometrial and Ovarian changes.

III. Secretory or Progetational or Pre-menstrual or Pre-decidual or Luteal Phase (15th to 28th day) : The endometrium increases in thickness upto 6 m.m. in length. The cells of the stroma proliferate. The uterine glands become elongated, dilated and convouted. The glandular secretion becomes greatly increased and more mucoid in character.

The corpus luteum is formed and attains maximum size on the 19th day, lasts upto 27th day and degenerates on the 28th day. The vaginal smear shows increased acoidphil cells. There will be proliferation of alveo-lobular system of the mammary gland and the gland is enlarged. The progesterone is secreted from the corpus luteum which inhibits further maturation of graafian follicles.

IV. Destructive Phase or Phase of Desquamation or Bleeding Phase or Stage of Menstrual flow (1 to 4 days) : This stage occurs if the ovum is not fertilized and after degeneration of corpus luteum. During this phase, the stratum compactum and stratum spongiosum together with some blood are cast off. The vaso-constriction in the mucosa towards the end of the luleal phase and resulting inchaemia of the endometrium lead to necrosis of the superficial layer. That is, superficial layers of the endometrium diminish in thickness, the circulation becomes slow and stasis occurs. Later the arteries again dilate, accompanied by the shedding of the necrosed tissue and bleeding occurs from the denuded surface.

Hormonal Control : The endometrial changes of the uterus are accompanied by cyclic changes in the ovary and ovarian hormones like Oestrogen and Progesterone. The cyclic changes in the ovary are controlled by the rhythmic discharge of F. S. H. and L. H. of anterior pituitary.

(a) **Regenerative Phase** : In this stage, the endometrium is slightly thickened and endometrial glands become small and tubular. It is regulated due to the action of oestrogen which has been secreted from the interstitial cells of the ovary by the action of Interstitial cell stimulating hormone of Anterior pituitary gland.

(b) **Proliferative Phase** : In this stage, the endometrium is 3 m. m in thickness, uterine glands become tortuous and endometrial blood vessels become coiled. It is regulated by the action of increased oestrogen and slight progesterone.

(c) **Secretory Phase** : In this stage, the endometrium is 6 m. m. in thickness, uterine glands become dilated and endometrial blood vessels become elongated. It is regulated by the action of progesterone in increased amount which is produced from corpus luteum of the ovary.

(d) **Destructive Phase** : In this stage, Progesterone and Oestrogen level diminished producing rapid degeneration of the corpus luteum. There will be sudden fall of progesterone due to rapid involution of the corpus luteum. The influence of progesterone upon uterine mucosa is withdrawn and thereby menstrual discharge takes place.

Q. 10. What is Oestrous Cycle ? Write briefly all you know about it.

A homologous condition of menstrual cycle during breeding season in lower mammals is known as the oetrous cycle. In this cycle, most female animals will only receive the male during a definite period in the reproductive cycle. The different phases of oestrous cycle are briefly described below :

(a) **Pro-Oestrous** : (*Preparatory Stage*) : The uterus becomes increased in size with growth of endometrium and extreme congestion due to the action of oestrogen secreted by the maturing follicles. The vaginal layer is proliferated and the vaginal smear shows nucleated epithelium in large number.

(b) **Oestrous** (*Heat Period*) : The uterus becomes congested, the vaginal-epithelium thickens further and the superficial cells are cornified. The vaginal smear shows non-nucleated acidophilic cornified cells. The ovulation takes place at this time so that impregnation is possible. If fertilisation takes place, placenta forms and pregnancy begins. During this period, the female will receive the male.

(c) **Metoestrus** (*Luteal Phase*) : The uterus becomes proliferated and secretion of glands, stroma cells and decidua take place due to the action of progesterone secreted by the corpus luteum. The vaginal smear shows large number of neutrophils along with keratinised cells. In absence of pregnancy, corpus luteum degenerates and the changes in the generative organs gradually subside.

(d) **Anoestrus or Dioestrus** : It is the resting asexual stage. In monoestrous animals like rabbit, it lasts upto the next mating season and is known as *anoestrus*. In polyoestrous animals like rats, guineapigs, mice, etc. the resting interval is short upto the next interval and is called *dioestrus*. The vaginal smear shows abundant degenerated leucoytes, few epithelial cells and mucous.

Q. 11. Give an account of the formation, structure and functions of Placenta.

The placenta in rough physiological language is double vascularised organ, made up of inter-digitating villi partly maternal and partly embryonic which brings the maternal blood in close connection with the offspring, thus establishing a respiratory and nutritive bridge between the mother and developing embryo. The placenta is an association between the embryonic and uterine tissue for the purpose of physiological exchange of materials.

Different Phases in Placenta Formation :

I. Early Development :

(*a*) **Preparation of the embryo for Placenta Formation** : After fertilization, the ovum descends and undergoes a sequence of morphogenic changes like segmentation, blastulation, gestrulation etc. and is converted into a three layered stage. After that a sudden change occurs in the outer covering of the embryo called trophoblast (trophoblastic ectoderm). Thin trophoblast soon differentiates rapidly into an outer layer called plasmotrophoblast and an inner layer or layers of cytotrophoblast.

(*b*) **Implantation of the Ovum** : The cyclic enzymatic activity of the trophoblast dissolves the uterine mucosa so that when the embryo comes in contact with the uterine wall it becomes surrounded by a cushion of liquified cells of blood called histotroph. Then the embryo fixes itself to some part of the corrugated maternal tissue sending finger-like projections called villi.

(c) **Primary Villi formation**: The plasmotrophoblast becomes a solid mass of multinucleated protoplasm and soon becomes vacuolated. The vacuoles are called primary lacunae. It pushes out here and there into the mucosa surrounding the implantation cavity and pushing out the somatic cells that approaches the capillaries and ultimately establishes a communication between the lacunae and the capillaries that cover the wall of the embryo. The lacunae then break up the trophoblast into trabeculae which give the entire chorion, a villus appears which may be called the primary villi.

(d) **Secondary or True chorionic villi formation**: The cytotrophoblast in the mean time has formed other villi which soon communicates within the chorion and as they move fowards the embryo, they are called as true villi.

II. **Later Development**: At first chorionic villi surround the whole embryo but later all the villi except that at the region between uterine muscular wall and chorion atrophy. The place where the chorionic villi are restricted is called chorion frondosum. Thus after full development the placenta consists of villi of chorion frondosum and part of the uterus in which the villi are lost.

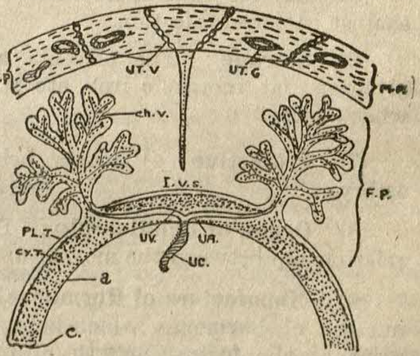


Fig. 12. Structure of Placenta. S. P.—Stratum Spongiosum, U.T.V.—Uterine vessels, U.T.G.—Uterine gland, M.P.—Maternal part, Ch. V.—Chorionic villi, I. V. S.—Inter-villious space, F.P.—Foetal part, P. L. T.—Plasmodial Trophoblast, a-aminion, c.—Chorion, U.V.—Umbilical vein, U.A.—Umbilical artery, U.C.—Umbilical Cord.

Structure of Placenta: The placenta consists of two parts—maternal and foetal.

(a) **Maternal Part**: This part is formed by decidua bacilis containing intervillous spaces. The greater portion of stratum compactum disappears but deep portion of this layer persists and becomes thickened to from basal plate, stroma, decidual cells and fibrinoid substances. The uterine arteries and veins pass to and from the intervillous space through stratum spongiosum, limiting layer and basal plate.

(b) **Foetal Part** : It consists of numerous finger-like processes formed by the secondary chorionic villi. These villi remain covered by a layer of syncytium known as Trophoblast and by its prolongations it is remain attached to the maternal decidua. The interior of villi are vascularised by umbilical vessels and the villi themselves are bathed in the maternal blood in the intervillous space carried by uterine arteries.

Functions of Placenta : The important functions are carried out by the placenta which are described below :

(1) **Nutritive** : Placenta supplies nutritive material from the maternal blood to the embryo through umbilical cord.

(2) **Excretory** : Placenta acts as the foetal kidney and excretes foetal metabolites from the embryo to the maternal blood.

(3) **Respiratory** : Placenta acts as the lungs of the foetus by performing simple gaseous diffusion.

(4) **Anchorage** : Placenta serves as an anchorage or fixation of the embryo by chorion formed by the false amnion. The body is anchored with the mother with the help of the placenta and its umbilical cord.

(5) **Barrier against Infection** : Placenta acts as a barrier against bacterial infection.

(6) **Storage** : The placenta acts as a store house of glycogen, fat, inorganic iron, etc. which are given to the embryo when needed.

(7) **Protective** : Placenta helps in the protection of the embryo.

(8) **Organ of Relationship** : Placenta acts as an organ of relationship between the mother and the foetus.

(9) **Manufacture of Hormones** : Placenta manufactures a number of hormones which help in the process of the development of the foetus, growth of mammary gland, uterus and placenta itself and also helps in the processes of lactation. The different types of placental hormones are as follows : (i) Placenta secretes *chorionic gonadotrophin* from foetal chorionic villi. (ii) Placenta secretes *oestrogen* specially during pregnancy. (iii) Placenta secreates *progesterone* in the later month of pregnancy. (iv) Placenta secretes an *anterior pituitary like hormone*. (A. P. L.). (v) Placenta itself elaborates an *oxytocic substance* which functions during parturition. (vi) Placenta is responsible for the liberation of a hormone known as *Relaxin*. It helps in the relaxation of the ligament of the symphysis pubis.

Q. 12. Describe the development, structure and functions of Mammary gland.

The mammary glands though accessory organs of reproduction are really specialised sweat glands in the sub-cutaneous tissue of the anterior thoracic wall and secrete milk when functional. A little inferolateral to the centre of each mammary glands, there is a pigmented area, the areola, the centre of which is the nipple. The mammary glands remain rudimentary in males but functional in females after puberty.

Development of Mammary Gland : In infancy and chilhood, mammary glands remain rudimentary. The development takes place at puberty and still more development takes place during pregnancy. In general, the development of mammary gland takes place in three stages—pre-natal, neo-natal and post-natal life.

(*a*) **Pre-natal development** (Before birth) : This type of development takes place in foetal life or before birth. In both male and female, ectodermal glands evolve in all vertebrates. This development takes place in different ways at defferent periods.

(1) *By 6th week* : A "milk ridge" is developed which is a condensation of the ectoderm and it extends from axilla to groin.

(2) *In 3rd month* : During this period, a "mammary pocket" is developed which appears a depression at the centre.

(3) *In 5th month* : The solid buds grow from the depressed mammary pockets.

(4) *From 7th to 9th month* : There will be canalisation of buds and these buds grow, divide and sub-divide to from lobules and central cells degenerate to form canal.

(*b*) **Neo-natal development** (At birth) : Just at birth the inverted nipple of the mammary gland becomes everted and in female baby a peculiar type of milk has been secreted which is known as "Witch's milk" due to oestrin action of the mother called "Mastities Neonatarum".

(*c*) **Post-natal development** (After birth) : In this stage, the mammary gland develops in different ways and in different phases.

(1) *Before puberty* : Mammary gland develops normally and becomes rudimentary both in male and female.

(2) *At puberty* : The gland enlarges in size due to deposition of fat. 15 to 20 lactiferous ducts divide and subdivide to form the ducts and alveoli, so that each lobe divides into lobules. The nipple also enlarges in size.

(3) *During menstruation* : The glandular part of the mammary gland will proliferate.

(4) *In between puberty and menstruation* : There is hyperaemia and deposition of fat leading to more and more development during the puberty period.

(5) *During pregnancy* : The mammary glands reach fullest development and are capable of secreting milk. The old alveoli proliferate and new alveoli are formed. The lining epithelium of the alveoli are columnar in shape and contractile myoepithelial cells surround the alveoli. The involuntary muscle fibres are present surrounding the duct and below the nipple. Plenty of nerve fibres are present in the nipple.

(6) *After parturition* : There will be irritation of secretory activity and enlargement of mammary gland takes place due to the accumulation of the secreting materials.

(7) *At menopause* : Involution takes place, glands atrophies, fatty tissue degenerates and only fibrous tissues persist.

(8) *In old age* : The fat and connective tissues disappear and the gland involutes.

Structure of Mammary gland : The structural constituents and pattern of the mammary gland differ in different phases of life in female. (Fig.13)

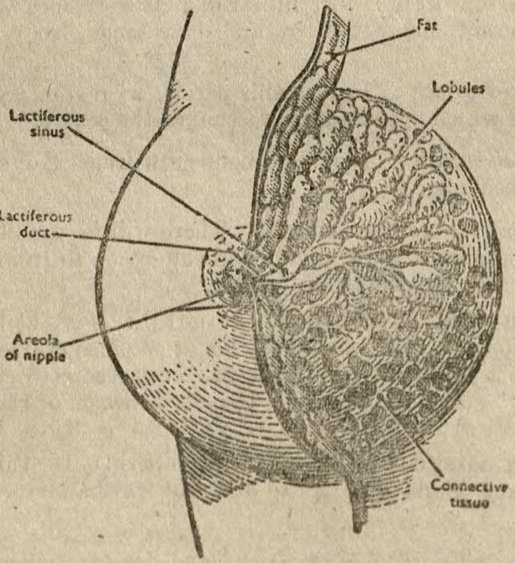


Fig. 13: Structure of the Mammary Gland showing its different structures.

(a) **At Birth :** The gland is rudimentary, consisting of little more than the nipple and lactiferous ducts are lined by single or double layer of epithelial cells which secrete fluid known as witch's milk that is similar to milk but free from fat.

(b) **At Puberty :** The structural components of the mammary gland are composed of glandular tissue, fibrous and fatty tissues.

(1) *Glandular tissue* : It is divided into 20 to 25 lobes by septa. Each lobe consists of several lobules connected together by areolar tissue, blood vessels and ducts. The minute ductules unite to form 15 to 20 lactiferous ducts. The alveoli are lined by glandular polyhedral cells during the resting condition and short columnar cells during activity which are supported on basement membrane. The myo-epithelial cells are present longitudinally along the ducts. The plain muscles are found in ducts and in the nipple.

(2) *Fibrous tissue* : The tissue surrounds the entire surface of the gland and sends down septa dividing the gland into lobes.

(3) *Fatty tissue* : This tissue maintains the form, size and shape of the mammary gland.

(c) **During Pregnancy** : The breasts become markedly changed in size and structure. During the first half of pregnancy no milk is secreted but in the latter half the epithelial cells swell and initiate secretory activity.

(d) **At Menopause** :The ectodermal elements, duct systems and acini are replaced by fat deposited in the stroma of the breast.

Functions of the Mammary gland : The functions of the mammary gland are as follows :

(1). Mammary gland helps in the formation of milk just after the birth of a baby. During the first half of pregnancy no milk is secreted but in latter half the epithelial cells swell and initiates secretory activity. After parturition, the milk is coming out from the nipple of the mammary gland. The secretion of milk stops during pregnancy, before puberty and after menopause. (2) It is an identification of mammals. (3) It is of interest to the body. (4) Mammary gland is a subject of poet for writing poetry, artist for drawing an artistic figure and sculpture for preparing a marvellous status.

Q. 13. How the development of breast is controlled ?

The development of breast is due to the complex action of the hormones and the intrct nerve supply.

I. **Nervous Control** : The nervous mechanism of the development of mammary gland is responsible for the intact nerve supply.

An intact nerve supply is not essential for the growth of the mammary gland during pregnancy. The breast may be completely transplanted, thus serving all its nervous connection it may yet grow during pregnancy and function although somewhat inefficiently after parturition.

II. **Hormonal Control** : There are a number of hormones responsible for the development of breast.

(a) **Role of Oestrogen** : Oestrogen is produced from the interstitial cells of the ovary by the influence of I.C.S.H. of anterior pituitary. It is responsible for the proliferation of the ducts of the mammary gland. During infancy and childhood oestrogen are not secreted, hence breast remain rudimentary.

(b) **Role of Progesterone** : This hormone is produced from corpus luteum by the influence of the lutenizing hormone of the anterior pituitary. It is responsible for the growth of alveolar system of the mammary gland.

(c) **Role of Placenta** : As pregnancy advances, the placenta becomes more important source of oestrogen and chorionic gonadotrophin, a less important source of progesterone and a source of small amounts of prolactin and A.C.T.H. The involution of the mammary gland occurs if the placenta is removed even though the ovaries and pituitary are left intact. It seems that placenta is indespensible for the full mammary gland development and can substitute for the ovaries as well as for the pituitary.

(d) **Role of Hypophysis** (Pituitary) : The pars anterior of the hypophysis plays an important and multiple role in the development of mammary gland. The oestrogen and progesterone have got a role over the mammary gland development.

III. **Mechanical Control** : (1) Before puberty, there is no mechanical effect over the mammary gland due to its undeveloped condition. (2) Breast is developed after puberty due to some mechanical effect. Suckling stimulates lactation by reflex mechanism and mechanical means. The mechanical process drains away the accumulated milk and makes spaces for fresh secretion.

Q. 14. Discuss the mechanism of discharge of milk.

The mechanism of discharge of milk consists of two phases known as milk secretion and milk ejection.

I. **Milk Secretion** : The secretion of milk consists of two processes which are discussed as follows :

(a) **Lactogenesis** : It is a process of the initiation of the secretion of milk. Though some secretion is present in the breasts during the latter part of pregnancy, a free flow of milk is established only some days after delivery of the child.

Lactogenesis is controlled in the following ways : During pregnancy, the gravid uterus is distended and afferent impulses will inhibit hypothalamus which will then inhibit anterior pituitary gland and therefore there will be no secretion of prolactin and no secretion of milk. But after delivery, the uterus will no more inhibit hypothalamus, hypothalamus will then stimulate anterior pituitary gland to secrete prolactin which will then stimulate the mammary gland to secrete milk.

(b) **Galactopoiesis** : It is a process of maintenance of secretion of milk. This is controlled chiefly by hormonal factors. The prolactin hormone is much more important for initiating than for maintaining milk secretion.

II. **Milk Ejection :** The discharge of milk from the mammary gland depends not only on the suction exerted by the infant, but also on a contractile mechanism in the breast which express milk from the alveoli into ducts. The suckling stimulates lactation in two ways :

(a) **Mechanical** : By this process, it drains away the accumulated milk and makes room for fresh secretion.

(b) **Reflex** : The process of suckling reflexly stimulates anterior pituitary gland, which secretes more prolactin hormone. During suckling, the afferent impulses from the nipple reach the hypothalamus, then through the hypothalamo-hypophyseal tract, neurohypophysis is stimulated and helps in the secretion of oxytocin hormone from posterior pituitary gland. The oxytocin hormone also stimulates the anterior pituitary gland to secrete prolactin hormone. So, suckling produces both secretion and ejection of milk.

Q. 15. Write short notes on ;

(1) **Leydig Cells :** These are known as interstitial cells present within the testis and secretes testosterone hormone. *Situation* : The cells of Leydig are found inside the stroma and between the seminiferous tubules of the testis. *Structures* : These are groups of polyhedral cells with rich protoplasm and well marked nuclei. The cells contain yellow pigment granules and are arranged usually round the blood vessels. The electron microscopic observations indicate that cells of Leydig contain highly developed agranular endoplasmic reticulum. *Distributions* : The cells of Leydig are abundant in early foetal life, fewer in newborn, continue to diminish to the end of childhood, markedly increases in number of puberty and diminish in old age. *Functions* : The cells of Leydig are probably to be concerned in the formation of testosterone hormone that serves the functions of growth of accessory male sex organs, develop-

ment of male secondary sexual characters, fertilising power of spermatozoa, muscular development and effect on growth of skeletal system of the body.

(2) **Androgen or Testosterone** : It is a male sex hormone secreted from the interstitial cells of the testis. *Formation* : (i) The androgen hormone is secreted from the interstitial cells or cells of Leydig of the testis of the male individual. (ii) This hormone is secreted from the adrenal cortex in traces. *Chemistry* : The androgen hormones are sterol compounds. *Varieties* : There are two types of androgen hormone which are natural and synthetic. The natural androgen is called testosterone. *Degradation Products* : The chief degradation products are the androsterone and dehydroepiandrosterone. *Functions* : (i) This hormone helps in the growth of accessory male sex organs like seminal vesicles, prostate, epididymis, etc. (ii) It helps in the development of secondary sexual characters in male individual. (iii) It increases the fertilising power of spermatozoa. (iv) It serves the development of body musculature and increases deposition of calcium salts of the bone serving growth of bone in the body. (v) It increases the development of red blood cells and maintains water balance of the body.

(3) **Sex hormones** : The sex hormones are the hormones liberated from the gonads and serve the functions of sex activity. *Formation* : The sex hormones are liberated from the gonads i.e. both from the interstitial cells of testis and the interstitial cells and corpus luteum of the graafian follicle of the ovary. *Varieties* : The sex hormones are of male and female varieties : (i) *From Testis* : Testosterone and androgen hormones are liberated from the interstitial cells of the testis. (ii) *From Ovary* : The interstitial cells of the ovary secretes oestrogen and the corpus luteum secretes progesterone and relaxin hormones. *Functions* : (i) The testosterone and androgen hormones serve the functions of the growth of male sex organs, development of secondary sexual characters in male, muscular development, growth of bone and water balance regulation etc. (ii) The oestrogen hormone serves the functions of puberty changes, development of primary sex organs and secondary sexual characters in female, controls the proliferative stage of menstruation and development of mammary gland etc. (iii) The progesterone hormone serves the functions of puberty changes, development of primary sex organs and secondary sexual characters in female, responsible for the premenstrual changes of uterine mucosa and development of breasts etc. (iv) The relaxin hormone causes relaxation of the pelvic ligament during pregnancy and parturition process.

(4) **Progesterone** . It is one of the ovarian hormones secreted from the corpus luteum and is responsible for gestation and

many other changes in the female individual associated with pregnancy. *Formation* : The progesterone hormone is liberated from corpus luteum, adrenal cortex and placenta. *Varities* : There are two types of progesterone compound known as Natural such as pregnanediol glycuronate and synthetic such as pregnanediol. *Functions* : (i) It helps in the growth of primary sex organs and development of secondary sexual characters in female. (ii) It controls the secretary phase of the menstrual cycle. (iii) It helps in the proliferation of alveolobular system of the mammary gland. (iv) It helps in the formation of placenta.

(5) **Ovulation** : It is a process by means of which ova is coming out from the ruptured matured graafian follicles of the ovary. *Occurrence* : The ovulation usually takes place between 12th to 16th days (average 14th day) after the first day of last menstruation. *Control* : The ovulation takes place by the action of follicle stimulating hormone (F. S. H) of the anterior pituitary upon the matured graafian follicles of the ovary. *Fate* : After ovulation, corpus luteum. grows on the ruins of the ruptured graafian follicles. *Functions* : (i) The ovulation indicates the true vergin condition of the female and has got academic importance. (ii) It bears a more constant relation with the menstrual cycle that follows it.

(6) **Corpus luteum** : The corpus luteum grows on the remains of the ruptured graafian follicles that secretes progesterone and relaxin hormones. *Formation* : After the discharge of the ovum, the cavity of the ruptured graafian follicles become filled up ultimately by yellow lipoid material and corpus luteum is formed. The corpus luteum is formed on about the 13th day of menstruation and continues to grow for 5 days. In absence of pregnancy, it persists upto 27th day of menstrual cycle and gradually degenerates. *Structures* : (i) The small central cavity is filled up with blood. (ii) The lining membrane of the graafian follicle collapses in folded layer. (iii) The lutein and paralutein cells are present within it. (iv) It consists of delicate strands of vascular connective tissue elements of theca interna. *Control* : The growth and secretion of corpus luteum is controlled by the leutenising hormone (L.H.) of anterior pituitary gland and placental gonadotrophins. *Fate* : The corpus luteum persists upto 27th day of the menstrual cycle and after that it will degenerate and will be replaced by fibrous tissue known as *corpus luteum albicans*. The hypertrophied corpus luteum which is found during pregnancy is known as *corpus luteum verum*. *Functions* : The corpus luteum secretes progesterone and relaxin hormones which are essential for gestation and many other changes associated with pregnancy.

(7) **Menstrual Cycle** : It is the cyclic bleeding due to the

cyclic changes of the endometrium occuring throughout the reproductive life of female. *Duration* : There is a flow of blood and mucous from the uterus due to the disintegration and shedding of the endometrium in every 28±3 days and lasting from 4 to 5 days in each time. *Occurrence* : It occurs every month from puberty to menopause and is absent before puberty and after menopause and during pregnancy and lactation. *Composition* : The menstrual material is composed of blood (30 to 40 ml.), stripped off endometrium, mucous, leucoytes and an unfertilised ovum. The amount of blood lost in each menstrual cycle varies from 50 to 250 ml. *Different Phases* : (i) Regenerative phase lasting from 5th to 7th day with 1 m.m. thick endometrium, small and tubular endometrial glands and small stroma cells. (ii) Proliferative phase lasting from 8th to 14th day with 3 m.m. thick endometrium, tortuous and enlarged mucous glands and delicate uterine vessels. (iii) Secretory phase lasting from 15th to 28th day with 6 m.m. thick mucous membrane, more enlarged and distended mucous glands and dilated uterine blood capillaries. (iv) Destructive phase lasting for 4 to 6 days with shedded endometrium, blood and mucous and discharge of an unfertilised ovum. *Hormonal Control* : (i) The regenerative phase is controlled by the action of oestrogen. (ii) The proliferative phase is controlled by the action of oestrogen and F.S.H. of anterior pituitary gland which is finally inhibited by high oestrogen level. (iii) The secretory phase is done by the progesterone hormone which is controlled by L. H. and L.T.H. of anterior pituitary gland. (iv) The destructive phase is caused due to the lack of progesterone hormone due to the rapid degeneration of the corpus luteum.

(8) **Placenta** : The placenta is a double vascularised organ, made up of inter-digitating villi partly maternal and partly embryonic which brings the materal blood in close connection with the offspring, thus establishing a respiratory and nutritive bridge between the mother and the developing embryo. *Formation* : The placenta has been formed from two sources : The part of the chorion in contact with decidua bacilis is responsible for the formation of the foetal part of the placenta and is called placental chorion or chorion frondosum. The maternal part of placenta is developed from decidua bacilis. *Structures* : (i) The maternal part is formed by decidua bacilis containing intervillous spaces. The deep portion of stratum compactum becomes thickened to form basal plate, stroma, decidual cells and fibrinoid substances. The uterine arteries and veins are present there. (ii) The foetal part consists of numerous finger-like processes formed by the secondary chorionic villi. The interior of villi are vascularised by umbilical vessels. *Functions* : (i) Placenta serves as an anchorage or fixation of the embryo to the uterine wall by

chorion formed by the false amnion. (ii) It helps in the protection of the embryo. (iii) It supplies nutritive materials from the maternal blood to the embryo through umbilical cord. (iv) It acts as a store house of glycogen, fat etc. which are given to the embryo when needed. (v) It acts as an organ of relationship between the mother and the foetus. (vi) It acts as the "lungs of the foetus" by performing simple gaseous diffusion by taking up oxygen and giving up carbon dioxide to the maternal blood and takes active part in gaseous exchange. (vii) It acts as the foetal kidney by transferring the wastes from the embryo to the materal blood through diffusion. (viii) It acts as a barrier against bacterial infection. (ix) It secretes an anterior pituitary-like hormone (APL). (x) It itself elaborates an oxytocic substance which functions during parturition process.

(9) **Graafian follicle** : It is the developed germinal epithelium of the ovary containing ovum and performs the function of maturation of ova and secretes oestrogen hormone. *Formation* : The ovary is covered with a layer of cubical cells called germinal epithelium which are ultimately cut off from the surface and undergo further development to from the graafian follicle. *Structures* : The cavity thus formed in the graafian follicle after ovulation into two layers : (i) The peripheral layer is known as membrana granulosa and (ii) The central layer is called discuss proligerous. The storma cells surrounding the graafian follicle becomes differentiated into two layers : (i) The outer layer is fibrous in character and is known as theca externa or tunica fibrosa. (ii) The inner layer is vascular in character and is known as theca interna or tunica vasculosa. *Control* : The early maturation of graafian follicle is done by F.S.H. of anterior pituitary gland but full maturation of the follicle is done both by F.S.H. and L.H. of the anterior pituitary gland. *Fate* : The graafian follicles have the following fates : (i) Before puberty, the maturation of the graafian follicle is incomplete and the ovum dies which is phagocytosed by the granulosa cells. (ii) Between puberty and menopause, about 500 graafian follicles undergo complete maturation and ovulation takes place. (iii) After ovulation, corpus luteum grows on the ruins of the ruptured graafian follicles. (iv) After menopause, all the remaining graafian follicles degenerate. *Functions* : (i) The graafian follicle forms mature ova. (ii) It secretes oestrogen and oestradiol. (iii) It provides a medium for the growth of corpus luteum.

CHAPTER
THREE

NERVOUS SYSTEM

Introduction : The system that controls and regulates the various activities of an organism by perceiving stimuli, transmitting these to various body parts and to effect responses is known as *Nervous System.* It also signifies that changes take place in the organism due to the changing conditions of the enviornment.

The nervous system is ectodermal in origin. It consists of central or somatic nervous system and the autonomic nervous system. The *Central nervous system* consists of brain and spinal cord. Brain is broadly composed of Cerebrum, Cerebellum and Brain stem that comprises mid-brain, pons and medulla. The spinal cord comprises of cervical, thoracic, lumbar, sacral and coccygeal segments through which sensory and motor nerves become in and out. The *autonomic* nervous system consists of sympathetic and parasympathetic systems. The sympathetic system comprises of thoraco-lumbar fibres and the parasympathetic system comprises of cranio-sacral fibres.

Q- 1. What is Neurone ? Describe the structure and function of a neurone.

A neurone is a nerve cell with its two processes, the larger single process known as axon or axis cylinder which transmits the received impulses from the cell body and the smaller numerous processes known as dendron or dendrites which receive impulses from various parts of the body. So, a neurone is the structural and functional unit of the central nervous system.

Structure of a Neurone : A neurone is made up of a nerve cell which consists of a cell body known as Neurocyton or Nerve cell body and a long and short processes known as axon and dendron respectively. The processes are collectively called the *nerve fibres.*

(a) **Nerve Cell Body :** (Fig. 14) The nerve cells vary in size and shape in different parts of the body. Their sizes and froms may be stellate, round, pyramidal, fusiform etc. According to the number of processes, the cell may be *Apolar*, *Unipolar*, *Bipolar or*, *Multipolar*. The nerve cell contains nucleus, mitochondria, golgi apparatus, pigments. Nissl granules, neurofibrils etc. in its cytoplasm.

(1) *Nucleus* : It is generally large, clear, spherical and often presenting an intracellular network of chromatin. It usually lies in the middle of the cell body and contains a well marked nucleoli.

(2) *Nucleolus* : It is generally large and distinct, situated within the nucleus.

(3) *Centrosome* : It is absent in a nerve cell and thus fully matured nerve cell never multiply.

(4) *Neurofibrils* : These are delicate threads which run through the cytoplasm in every direction from the dendrite to the axon of the cells and are believed to be the actual conductors of nerve impulses.

(5) *Nissl Bodies* (Nissl granules or Tigroid substance) : It is found in the protoplasmic mass of the cell body, in the dendrites, in the sympathetic ganglionic cells and excepting the axon hillock from where the axis cylinder arises. They are spindle-shaped angular masses of basophilic material present in the cytoplasm. Under certain conditions, the Nissl granules disintegrates and disappear which is known as *Chromatolysis.* During rest the granules reappear. It has been suggested that the Nissl granules act as a catalysing agent in increasing the metabolic activity of the cell and are intemately connected with the nutritional condition of the neurone.

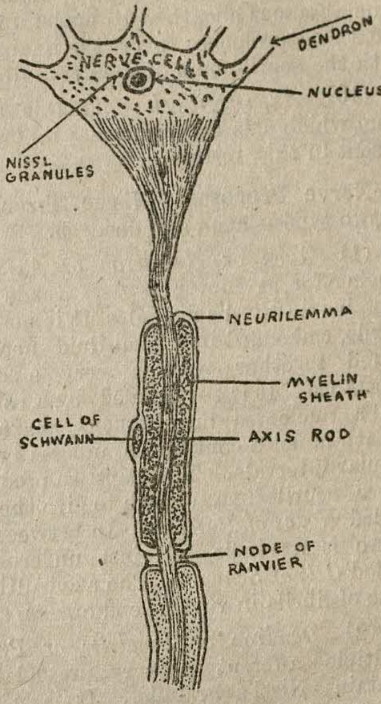


Fig. 14. Structure of a Typical Neurone showings.its different components,

(6) *Cytoplasm* : The cytoplasm is characterised by the presence of basophil granules and neurofibrils which are easily seen by cajal's method of staining.

(7) *Mitochondria* : It is scattered in the cytoplasm as small rodlets and granules and is visible in the living state. There are phospholipid-protein inclusions. It is believed that mitochondria secrete the enzymes which help in the metabolism of cell body.

(8) *Golgi Apparatus*: It is a network found in the cytoplasm. It extends partly into the dendrons but not into the axon.

(9) *Membranous Sheath*: Each nerve cell is covered by a membranous sheath with nuclei upon its inner surface. This sheath is prolonged over the issuing fibres and is continuous with the neurilemma of the nerve fibres.

(10) *Axon Hillock*: This is a swelling in the cell body from which axis cylinder takes its origin. The Nissl granules are absent in this region.

Nerve Processes (Nerve fibres) : The nerve processes are of two types—axon and dendron.

(1) *Axon or Neuraxon or Axis Cylinder*: It is the main single efferent motor process tends to be straight and long, contains no Nissl's granules. It is made up of numerous primitive fibrils, embedded in a semi-fluid neuroplasm. These fibrils are bound together with a very small amount of interfibrillar substance. It is surrounded by a relatively thick *myelin sheath* and a nucleated membranous *neurilemma sheath.* The myelin sheath is not a continuous process but there are interruptions at regular intervals. The gaps so produced are invaginated by the outer neurilemma sheath to give the appearance of constrictions called *Nodes of Ranvier.* In between the two nodes of Ranvier there is a single cell just underneath the neurilemma sheath called *Cell of Schwann.* The axon ultimately ends in an arborescence of fibrils in various end organs, sympathetic nerve cells etc.

(2) *Dendron or Dendrite or Protoplasmic process*: It is multiple afferent sensory protoplasmic process of nerve-cell contains Nissl's granules. It is usually branch in a spreading manner with frequent bifurcations like the branches of a tree and finally end in minute twigs and become lost in other elements of nervous tissue.

Functions of Neurone : The neurone comprising the nerve cell and nerve processes perform the following functions :

(a) *Functions of a Nerve Cell Body* : (1) The nucleus with nucleolus maintains the vitality of nerve cells. (2) The neurofibrils are believed to be the actual conductors of nerve impulses. (3) The Nissl's granules are intemately concerned in the metabolic activity of the cell and are closely connected with the nutritional condition of the neurone. (4) According to *Penfield*, the golgi apparatus is an even more sensitive index of activity of of the nerve cell than the state of the Nissl substance.

(b) *Functions of Nerve Processes* : (1) The axon carries nerve impulse away from tho cell-body. (2) The dendron collects impulses from other neurones and carries those nerve impulses towards the cell body. It performs amoeboid movements under the action of mechanical, chemical or thermal stimuli.

Q. 2. Write down the difference between Axons and Dendrons.

The axons and the dendrons are the two processes of a nerve cell and form a neurone which is the structural and functional unit of the central nervous system. The main differences between axons and dendrons are as follows :

Axons	**Dendrons**
1. The axon is a single large process arises from the axon hillock of a nerve cell body.	1. The dendrons are short numerous processes arise from the different regions of the nerve cell body.
2. It contains no Nissl granules.	2. It contains Nissl granules.
3. The axons branch after a long course into terminal ramification called *telendendron.*	3. The dendrons branch rapidly.
4. The axons are smooth and diminish very slightly in their course.	4. The dendrons are rough and rapidly diminish in size.
5. The axons are enveloped in sheaths either neurilemma or medullary sheath or both.	5. The dendrons are naked to their terminations.
6. The axons give off fine collateral branches without any diminution in calibre.	6. The dendrons give off irregular branches.
7. The axons transmit the received sensory impulses to the different parts of the body.	7. The dendrons receive the sensory impulses from the neighbouring structures of the body through other neurones.

Q. 3. What is Synapse ? Describe the formation, properties and functions of synapse.

The synapse is a neuro-neural junction where one neurone ends and arborises with the nerve cell by its processes and other begins from there. It is the basic functioning unit of the central nervous system.

Formation of Synapse : The synapse may be formed by the following ways : (1) Between the axon of one neurone and the dendrite of the other form *axodendritic synapse.* (2) Each terminal nerve fibril of the axon ends in a small knob-like button and may embrace the membrane of the dendrites and as well as the ganglion cell body of the next neurone forming a net work around them. It forms *axo-somatic synapse.* (3) The presynaptic fibres of any axon ends in the axon of the postsynaptic cells and form *axo-axonic synapse.*

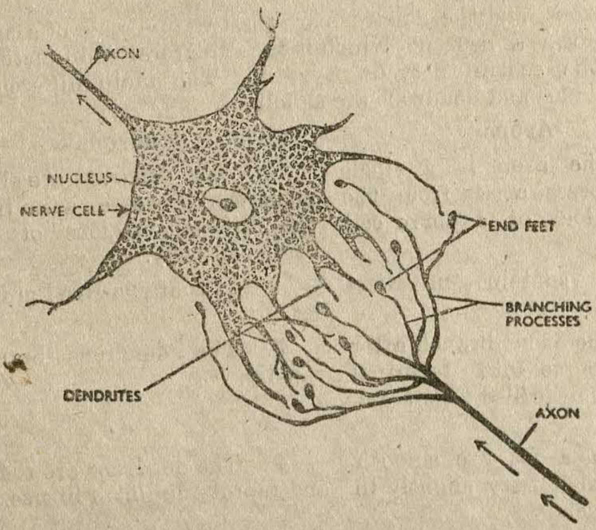


Fig. 15. Diagrammatic representation of a formation of a synapse.

Properties of Synapse : The synapse possesses a number of properties which are the following :

(1) **One-way transmission of Impulse** : An impulse is always passed through a synapse from the axon of one neurone to the dendrite of the other i.e., in one direction only.

(2) **Synaptic delay** : The transmission of impulse is usually retarded while passing through a synapse. It depends upon the number of terminal knobs and the type of ganglion cell.

(3) **Synaptic block :** A ganglion cell always offers resistance against the passage of an impulse even in the usual direction.

(4) **Seat of fatigue** : Synapse is the physiological seat of fatigue in the central nervous system.

(5) **Summation :** The repeated discharges of a single terminal knob increases the total density of negative charges outside the cell membrane.

(6) **Facilitation :** The passage of one impulse facilitates

the passage of next subsequent impulses. In this way the response of one ganglion cell can be altered by activities in other areas of central nervous system.

(7) **Distributing action** : A nerve impulse received from one neurone may be distributed to many other neurones which communicate through a common synapse.

(8) **Convergence** : A number of different nerve fibres can converge on a single nerve cell. The anterior horn cell is the final common pathway of a number of impulses coming through different neurones.

(9) **Divergence** : A single afferent impulse can be amplified through several stages of divergence and then stimulate a number of nerve fibres simulaneously. A single pyramidal cell can excite many intermediate cells in the spinal cord and can stimulate a number of muscle fibres.

(10) **Commutator action** : Synapses can alter the path of an impulse in many directions by offering degrees of resistance.

Functions of Synapse : A synapse performs the following functions. (1) It relays nerve impulses and transmits the impulses in all directions, apparently without any change of quality of the impulse. (2) It selects which impulses are to be allowed to pass and which ones are to be blocked. (3) It sometimes amplifies the afferent nerve impulses, so that one impulse may elicit many efferent impulses. (4) The synapse sometimes decreases the number of transmitted impulses.

Q. 4. What are Receptors ? How can you classify them ? Give a brief account of different cutaneous sensation.

Receptors are specialised structures which have developed with the object of responding to a particular type of change in the enviornment. The afferent nerve impulse normally originates from the stimulation of the receptor with adequate stimuli.

Classification of Receptors : According to structure and function, receptors may be of various types like somatic and autonomic nerve endings and they are following : (Fig. 16)

I. **Exteroceptors** :

(A) Cutaneous Receptors :

(a) **Encapsulated Endings** :

(1) For **Touch** : *Meissner's Corpuscles* (Tactile corpuscles) and *Merkel's discs.*

(2) For **Heat** (warmth) : *Organ of Ruffini.*

(3) For **Cold** : *End bulb of Krause.*

(4) For **Pressure** : *Organ of Golgi-Mazzoni,*

(5) For **Deep Pressure** : *Pacinian Corpuscles.*

(b) **Free Nerve Endings and Plexus** : (without any special body).

(1) For **Pain** : Free nerve terminals known at 'Nociceptors".

(2) For **Fine Touch** : Free terminals around hair roots.

(B) **Special Sense Receptors** :

(a) **Teloreceptors** (Distance Receptors) :

(1) For **Vision** : *Rods and Cones* of Retina.

(2) For **Audition** (Hearing) : *Organ of Corti* of Cochlea of the internal ear.

(b) **Chemical Receptors** :

(1) For **Smell** : *Olfactory cells* of nasal mucosa.

(2) For **Taste** : *Taste buds* of Tongue.

II. Interoceptors :

(A) **Proprioceptors** (Kinaesthetic) :

(a) For **Muscle Sense** :

(1) Muscle spindle—Stretch afferent.

(2) Golgi tendon organ—Tension recorders.

(3) Pacinian Corpuscles—Deep pressure.

(4) Free nerve endings subserving pain—Blood vessels of both muscles.

(b) For **Position Sense** (Labyrinthine Impulses) : *Saccule, Utricle* etc.

(B) **Visceral Receptors** (Autonomic) :

(a) For **Pain** : Non-medullated free terminals.

(b) For **Stretch** and **Tension** : Hollow organs, Capsules, Serous membranes etc.

(C) **Vascular Receptors** *or* **Chemo-receptors** *or* **Osmoreceptors** : They are sensitive to chemical changes of blood and are found in the cells of aortic and carotid bodies.

(D) **Conscious Receptors** : These receptors include Hunger, Thirst, Sexual desire and Kindred perceptions.

Descriptions of Different Cutaneous Sensations : The cutaneous receptors are present in the skin structure and responsible for the sensation of pain, touch, pressure, hot and cold etc.

I. Pain Sensations :

(a) **Sensory End Organs** : (1) Free Nerve endings and (2) Blood plexus.

(b) **Histology** : The free nerve endings come both from myelinated and from non-myelinated nerve fibres, the latter often penitrating the epidermis and forms a deep primary plexus and then a superficial secondary plexus.

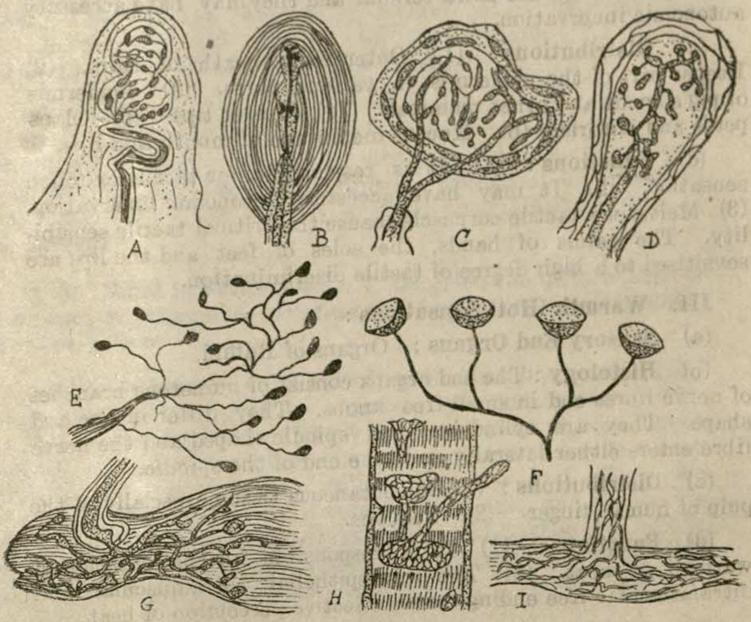


Fig. 16. Different Type of Receptor or Nerve Endings. A—Meissner's Corpuscle (Touch) ; B—Pacinian Corpuscle (Deep Pressure) ; C—End Bulb of Krause (Cold) ; D—Organ of Golgi Mazzoni (Heat) ; E—Free Nerve-terminals (Pain and Touch) ; F—Merkel's Disc (Touch) ; G—Organ of Golgi ; H—End Plates ; I—End Organ of Ruffini (Warmth).

(c) **Distributions** : (1) Free nerve endings of blood vessels and many visceral surfaces. (2) Non-myelinated plexiform networks deep in the epidermal and dermal layers of human skin. (3) Epithelium of the mucous membranes. (4) Epithelium of the cornea. (5) Root sheaths and papilla of hairs. (6) Around sweat glands. (7) Serous membranes. (8) Intermuscular connective tissue. (9) Dentine and pulp of the teeth.

(d) **Functions** : When the free nerve ending are stimulated it causes the sensation of pain sensibility.

II. Touch Sensations :

(a) **Sensory End Organs** : (1) Markel discs or Merkel's touch cells. (2) Tactile discs. (3) Meissner's corpuscles. (4) Hair root endings.

(b) **Histology** : It consists of cup-shaped terminal discs, reticulate in structure and generally several of the sensory discs are innervated by a single fibre. These end organs, unlike the free nerve endings are extra-cellular and they may have accessory autonomic innervation.

(c) **Distributions** : (1) Outer root sheath of hairs. (2) Deeper part of the epidermis in various parts. (3) Epidermis of pig's snout and other mammals. (4) Finger tips. (5) Glans penis and clitoris. (6) Mucous membrane of mouth and lips.

(d) **Functions** : (1) It is responsible for tactile or touch sensation. (2) It may have accessory autonomic innervation. (3) Meissner's tactile corpuscles cause the critical tactile sensibility. The palms of hands, the soles of feet and the lips are sensitised to a high degree of tactile discrimination.

III. Warmth (Hot) Sensations :

(a) **Sensory End Organs** : Organs of Ruffini.

(b) **Histology** : The end organs consist of numerous branches of nerve fibres end in small free knobs. They differ in size and shape. They are cylindrical and spindle shaped and the nerve fibre enters either laterally or at the end of the spindle.

(c) **Distributions** : (1) Sub-cutaneous tissue especially of the pulp of human finger. (2) Tendons.

(d) **Functions** : (1) It is responsible for the sensation of warmth or heat. (2) The intraepithelial, intramuscular and intrafascicular free endings cause effective perception of heat.

IV. Cold Sensations :

(a) **Sensory End Organs** : End bulb of Krause.

(b) **Histology** : The end organs are minute cylindrical or oval bodies consisting of a capsule containing a soft fluid core in which the axis cylinder terminates either as a bulbous extremity or a coiled up flexiform mass.

(c) **Distributions** : (1) Conjunctiva of the eyes. (2) Edge of the cornea. (3) Mucous membrane of the lips and tongue. (4) Epineurium of nerve trunks. (5) Serous membranes. (6) Tendons and aponeurosis.

(d) **Function** : It is responsible for the sensation of cold.

V. Pressure Sensations :

(a) **Sensory End Organs** : (1) Corpuscles of Golgi. (2)

Corpuscles of Mazzoni. (2) Pacinian corpuscles for deep pressure.

(b) **Histology** : The end organs are smaller than the Pacinian corpuscles, their corpuscles are thinner and the nerve ramify extensively and end in flat expansions in the central core.

(c) **Distributions** : (1) In sub-cutaneous tissue of the pulp of the fingers. (2) In papillary and sub-papillary layers of the dermis. (3) At the junction of tendons with their muscles. (4) Peritoneum. (5) Pleura. (6) Pericardium. (7) In the deeper part of the dermis of the hand and feet.

(d) **Functions** : (1) It is responsible for the sensation of pressure. (2) It is concerned with muscle and joint sense (kinaestheitc sense). (3) They are responsive to mechanical deformation. (4) They are regarded as endings of deep pressure sensibility. (5) They possibly respond to gravitational drag on the mesentry.

Q. 5. What is Reflex Action ? Describe the different parts and types of reflex arc. Discuss the important characteristics of reflex action.

A reflex action is an unconscious, involuntary, purely automatic motor response due to a sensory stimulus, performing by the lower centres only without the reference of the higher centres. The impluse arises from the receptor organs, passes through sensory and intermediate neurones and effects the effector organs (simple and voluntary muscles and glands) via motor neurones. The consciousness appears when the act is over. It is not an wilful action. Reflex action is not possible without reflex arc. It is only restricted to the central nervous system.

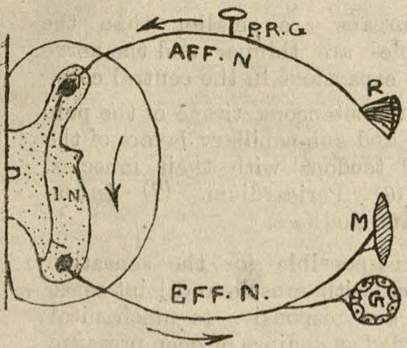
Parts of a Reflex Arc : For the production of reflex action there must be a reflex arc which consists of : (Fig. 17)

(a) **Receptors** : These are sensory surfaces receive sensory impluses and transmit these impluses though the sensory neurone. They may be cutaneous receptors, special sense receptors, proprioceptors, visceral receptors, conscious and special receptors.

(b) **Afferent Neurone** : It posseses posterior root ganglia and connects the receptors at one side and relay to the posterior horn cell to the other. It carries sensory impulses from receptors to centre.

(c) **Intermediate Neurone** : It is known as intercalated or internuncial neurone. It connects the posterior and anterior horn cells and the sensory stimulus is converted into motor impulse.

(d) **Efferent Neurone** : It arises from the anterior horn cells of spinal cord or cells of the cerebrum, cerebellum and brain stem. It consists of motor nerves and motor endings.



Fig, 17. A Reflx Arc.
R—Receptor ; P. R. G.—Posterior root ganglia ; AFF.N—Afferent neurone ; I.N.—Intercalated neurone ; EFF.N—Efferent neurone ; M—Muscle ; G—Gland.

(e) **Effector Organs** : These are plain muscles, voluntary muscles or glands where the motor neurones end.

Types of Reflex Arc : The reflex arc may be of several types :

(a) **Simple reflex arc** : It consists of two neurones such as afferent and efferent neurones.

(b) **Intercalated reflex arc** : It consists of three neurones. They are afferent neurone, efferent neurone and one intermediate neurone which is interposed between the afferent and efferent neurones.

(c) **Crossed reflex arc** : It consists of three neurones but the afferent and efferent neurones lie in the opposite side and the intermediate neurone joining them, crosses the spinal cord from one side to the other.

(d) **Complex reflex arc** : The axon of a sensory neurone gives collateral branches and each of these collaterals ends may around the nerve cells of efferent neurones and mayform seperate reflex arcs.

Characteristics or Important Properties of Reflex Actions.

(1) **Localisation** : Stimulation of a particular locality produces a particular type of response. Therefore the place of stimulation is to locate by the response of the motor neurone is known as *Localisation*.

(2) **Block or Resistance** : Slight stimulus on the sensory neurone causes motor response. Increase stimuluation on the sensory path produces chemical substances like acetyl choline and adrenaline which are adhered in the synapse causing block on the synapse that checks the transmission of impulse from one neurone to the other.

(3) **Co-ordination** : Due to the stimulation of the sensory neurone, many muscles are involved in a reflex action and it is

seen that their contractions and relaxations are so nicely adjusted that the reflex movements becomes smooth, accurate and purposeful. This phenomenon is known as *Co-ordination.*

(4) **Delay** (Reflex delay or Latent period) : It is a short interval between the application of stimulus and the onset of reflex response. The *total reflex delay* is the interval between the application of the stimulus to the afferent nerve and the onset of contraction in the muscle. When the latent peroid that elapses between stimulus and response in the flexor reflex is measured and the time taken in contractions along the nerve fibre is deducted, we get what is called the *central delay* or *reduced reflex time.*

(5) **Fatigue** : If a particular stimulus be too frequently repeated at short intervals, the reflex response will gradually diminish and finally there will be no reflex contraction of the muscle. This phenomenon is called fatigue. Nerve is infatiguable. The place of fatigue is in the synapse.

(6) **Refractory Period** : Once a reflex is elicited, a brief interval must be allowed to pass before it can be elicited for the second time. This period of depressed excitibilty following a response is called *refractory period.*

(7) **Facilitation** (Re-inforcement) : If a reflex be elicited repeatedly at proper intervals across a synapse, its resistance is diminished and thus the second stimulus provokes response more readily.

(8) **Summation** : It means the sum total effect of responses after giving a number of stimulus on the sensory neurone. If the stimulus be weak or sub-liminal, it will fail to elicit a response but when a series of weak stimuli are given to the same receptor, their effects will be summated together and ultimately there will be a response. The summation is of two types —*spatial summation* and *temporal summation.*

(9) **Subliminal fringe** : The tension produced by two afferent nerves combined is greater than the sum of the two reflex responses taken singly. The phenomenon of sub-liminal fringe is possible when some of the motor neurones are present in between the centres and not within the centres. When subliminal stimulus on area (A) and (B) are stimulated separately, there will be not elicit of response but when these two areas are stimulated, there will be response due to the sumtotal effect of individual stimulations.

(10) **Recruitment** : Due to the successive stimulation of the sensory neurone, we get more and more responses. In this way, we recruit more responses for increased stimulation on the sensory nerve.

(11) **Rebound** : Repeatition of responses without the repeatation of stimuli is known as *Rebound.* Due to single stimulation of the sensory neurone, all the intermediate neurones are stimulated but the response will not cause at a time, it will cause one after another. So repeatition of response is caused without the stimulation of sensory neurone repeatedly.

(12) **After discharge** : When one sensory path is stimulated, the response will occur one after another. The series of responses, going on one after another after the stimulation on the sensory neurone is over, is known as *After discharge.*

(13) **Occlusion** : When a stimulus is applied directly on the motor nerve of a muscle, the amount of contractions becomes much higher than when the same muscle is made to contract reflexly. It is due to the fact that some of the motor neurones are common to both and that the afferent fibres overlap in their central distribution.

Q. 6. Describe the different structures present in the transverse section of Spinal Cord.

The spinal cord is an elongated cylindrical column of nerve substance, somewhat more flattened in front than behind, (occupying the upper two-thirds of the spinal canal of the vertebral column.)

Structures present in the Section of Spinal Cord : The transverse section of spinal cord is composed of *grey* and *white matter*, the grey matter is in the interior and consists of two concentric masses connected together by the *isthmus* and perforated in the centre by the *central canal.* (The white matter surrounds the grey matter. The different structures that are found in the transverse section of the spinal cord, are as follows :

(A) **Central Canal** : It lies in the centre of the grey matter of the spinal cord. It is lined with a layer of columnar ciliated epithelial cells known as *ependyma* and is surrounded by the *substantia gelatinosa centralis.* The central canal actually pierces through the isthmus of the two symmetrical lateral halves of the grey matter. It runs the whole length of the spinal cord and widens into the fourth ventricle at the medulla oblongata.

(B) **Grey Matter** : It is a form of rough crescent shaped structure and has got three parts knows as *anterior horn*, *lateral horn* and *posterior horn.* The nerve fibres are present which are mostly of non-myelinated fibres supported by a group of neuroglial cells.

(1) **Nerve Cells** : There are a number of nerve cells present in the grey matter of the spinal cord which are the following :

(i) *Anterior horn cells* (Motor) : These are anteriorly placed wider portion of the central grey mass. From the nerve cell of the anterior horn, motor nerve fibres arise which supply the voluntary muscles of the body.

(ii) *Lateral horn cells* (Autonomic) : From the lateral portion of the grey mass the projected band of grey matter is known as lateral horn. From the nerve cells of the lateral horn, nerve fibres are distributed to the involuntary muscles, blood vessels, viscera and glands. These groups of cells belong to autonomic nervous system. The lateral horn cells are only present in the thoracic and the upper lumbar segment of the spinal cord.

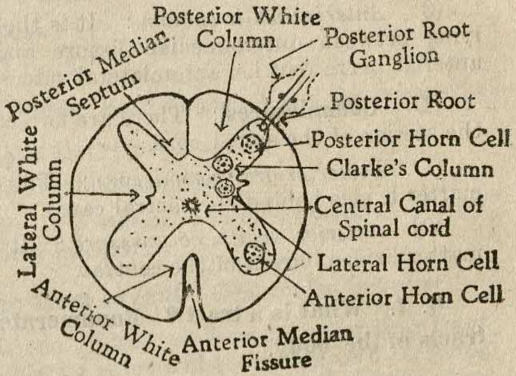


Fig. 18. Transverse Section of the Spinal Cord showing the arrangement of grey and white matter and nerve cells.

(iii) *Posterior horn cells* (Sensory) : The posteriorly placed grey matter is sub-divided into three anatomical land marks. These are tips of the posterior horn, the intermediate portion or body and the base which lies close to the lateral horn. The posterior horn cells acting as a relay station for the sensory impulses which are going from the periphery to the central nervous system.

(iv) *Clarke's Column* (Dorsal Nucleus) : At the base of the posterior horn, there is a group of nerve cells known as Clarke's column which acts as a relay station for the sensation coming from muscle, ligaments, tendons, bone etc. e.g. kinaesthetic sensations.

(2) **Neuroglia** : These are two in number which are :

(i) *Substantia gelatinosa Rolando* : A thin of gelatinous material which lies at the tip of the posterior horn is known as Substantia gelatinosa Rolandi.

(ii) *Substantia gelatinosa centralis* : It is a thin film of gelatinous material which lies in the central canal of the spinal cord. It is covered by ciliated epithelium known as ependyma.

(C) **White Matter** : The white matter surrounds the grey matter of the spinal cord and has been anatomically arranged as follows :

(1) *Posterior white column* : It is the area of white matter which lies between postero-median septum and the site of origin of the posterior nerve root.

(2) *Lateral white column* : It is the area of white matter lying between the sites of origin of anterior and posterior nerve roots.

(3) *Anterior white column* : It is the area of white matter lying between antero-median fissure and the site of origin of anterior nerve root i.e. anterolateral sulcus.

(D) **Commissures** : There are two commissures present in the section of the spinal cord.

(1) *Posterior grey commissure* : This is a part of the grey matter bridge behind the central canal.

(2) *Anterior white commissure* : It is a part of the grey matter bridge infront of the central.

Q. 7. What is a tract ? Ennumerate the different nerve tracts of the body.

A tract is a collection of nerve fibres carrying one or more motor or sensory impulses within the central nervous system.

Ennumeration of different nerve tracts :

I. **Ascending Tracts** (Sensory Tracts)

(1) Tract of Goll (Fasciculus Gracilis)

(2) Tract of Burdach (Fasciculus Cuneatus)

(3) Comma Tract of Schultze (Tractus Interfascicularis)

(4) Spino-thalamic Tract.

(5) Spino-tectal Tract.

(6) Dorsal spino-cerebellar Tract (Flechsig's Tract)

(7) Ventral spino-cerebellar Tract (Gower's Tract)

(8) Spino-reticular Tract.

(9) Spino-olivary Tract.

II. **Descending Tracts** (Motor Tracts) :

(A) Pyramidal Tract :

(1) Crossed Pyramidal Tract (Large lateral cortico-spinal tract).

(2) Direct Pyramidal Tract (Uncrossed anterior cortico-spinal tract).

(3) Uncrossed Pyramidal Tract (Small lateral cortico-spinal tract).

(B) Cortico-bulbar Tract.

(C) Extra-Pyramidal Tracts :

(1) Rubro-spinal tract.

(2) Tecto-spinal tract.

(3) Ponto-spinal tract.

(4) Vestibulo-spinal tract.

(5) Olivo-spinal tract.

(6) Reticulo-spinal tract.

III. **Inter-segmental Fibres** (Both ascending and descending).

(1) Ground bundle of anterior column.

(2) Ground bundle of lateral column.

(3) Ground bundle of posterior column—Posterior ground bundle and Septomarginal fasciculus.

Q. 8. Describe the Tract of Goll. (Fasciculus Gracilis)

The tract of Goll is one of the sensory or ascending tract passing through the posterior column of the spinal cord receiving afferent fibres from the lower half of the body and carries conscious kinaesthetic sensations.

Origin : This tract originates from the nerve cells in the posterior root ganglia of the lower thoracic, lumbar and sacral spinal nerves receiving sensory impulses from the muscles, joints tendon, ligaments and bones of the body. These processes will enter the spinal cord and will occupy the posterior white column.

Course, Termination and Relay : (Fig. 19) The fibres of the first order neurone after entering the white matter of the spinal cord run upward along the posterior column and end around the cells of nucleus gracilis in medulla on the same side. The second order neurone then starts from nucleus gracilis and follows main three paths : (1) The second order neurone fibre from the nucleus gracilis, passes through the inferior cerebellar peduncle of the same side and relays to the deep nuclei of cerebellum of the same side. The third order neurone then begins from deep nuclei and relays to the cerebellar cortex. These fibres are termed as the *Dorsal External Arcuate Fibres.* (2) The second order neurone fibre arising from the nucleus gracilis, crosses to the opposite side and passes through the inferior cerebellum. From there, third order neurone arises and relays to the cerebellar cortex. These fibres are known as the *Ventral External Arcuate Fibres.* (3) The second order neurone fibre arising from the nucleus gracilis, crosses to the opposite side and then ascends up through pons, tegmentum, substantia nigra, tectum part of mid-brain and ultimately relays to the posterior ventral nucleus of the thalamus. This fibre is known as *Internal Arcuate Fibre.* The third order neurones will take origin from the lateral nucleus of the thalamus and passes through the posterior 1/3rd of the posterior limb of the internal capsule and end in areas 3, 1, 2, 5 and 7 of post-central gyrus of sensory cortex.

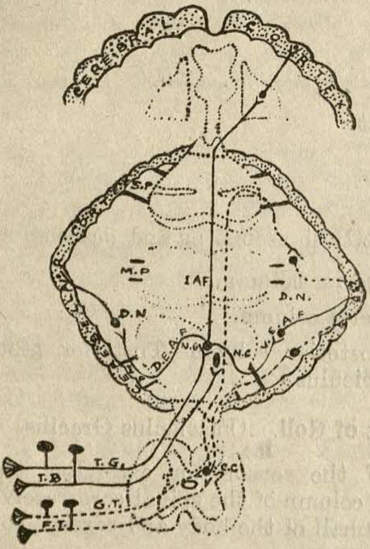


Fig. 19. Ascending Tracts.
T. G.—Tract of Goll. T. B.—Tract of Burdach, G. T.—Gower's Tract, F. T.—Flechsig's Tract, S. P.—Superior Peduncle, M. P.—Middle Peduncle, I. P.—Inferior Peduncle, D. N.—Deep Nuclei, D. E. A. F.—Dorsal External Arcuate Fibre, N. G.—Nucleus Gracilis, N. C.—Nucleus Cuneatus, V. E. A. F.—Ventral External Arcuate Fibre.

Functions : (1) The tract of Goll carries the sensations from the lower half of the body i.e. upto mid-thoracic region. (2) It carries the motorial conscious kinaesthetic sensations such as sensations from muscles, joints, tendons, ligaments and bones, subcutaneous tissue, fine touch, tactile localisation and tactile discrimination. (3) It also carries some unconscious kinaesthetic sensation to the cerebellum and helps the cerebellum to maintain the posture. (4) It carries vibration senses. (5) It may carry some afferent impulses for different supperficial reflexes.

Q. 9. Describe the Tract of Burdach (Fasciculus **Cuneatus**).

The tract of Burdach is one of the sensory tract passing through the posterior column of the spinal cord receiving afferent fibres from the upper half of the body and carries conscious kinaesthetic sensation.

Origin : This tract originates from the nerve cells in the posterior root ganglia of the upper thoracic and cervical spinal nerves receiving sensory impulses from the upper half of the **body**.

Course, Relay and Termination : (Ffg. 19) The tract of

Burdach ends in the nucleus cuneatus of the medulla oblongata. The further course is same as in the case of the tract of Goll.

Functions : (1) The tract of Burdach carries the sensation from the upper half of the body i.e. above the mid-thoracic region. (2) It carries the consicous kinaesthetic sensations such as sensations from muscles, joints tendons, ligaments and bones, sub-cutaneous tissue, fine touch, tactile localisation and tactile discrimination. (3) It also carries some unconscious kinaesthetic sensation to the cerebellum and helps the cerebellum to maintain the posture and equilibrium. (4) It carries vibration senses. (5) It may carry some afferent impulses for different superficial reflexes.

Q. 10. Describe the Comma Tract of Schutze (Semilunar Tract).

The comma tract originates from short deacending branches derived from the tracts of Goll and Burdach which looks like a 'comma' and establishes and inter-segmental communication.

Origin : This tract originates from the descending branches of the axons of the cells of the ganglia on the posterior roots of the spinal nerve derived from the tracts of Goll and Burdach.

Situation : It is a small oval bundle, stiuated in the thoracic region of the posterior column of the spinal cord like a 'comma' shaped bundle in tranverse section.

Course and Termination : Immediately on entering the spinal cord the fibres of the posterior root undergo a Y-shaped branching, one long brach courses longitudinally upward while the other short one courses downward for a short distance and froms the comma tract. The fibres end by arborising round the cells of the posterior horn of the spinal cord.

Functions : (1) It establishes an inter-segmental communication. (2) It helps to form short reflex arcs. (3) It performs the motor function because it contains motor fibres too.

Peculiarity : The peculiartity of this tract is that although sensory in function but it is descending in course.

Q. 11. Describe the Spino-Tectal Tract.

The spino-tectal tract arises from the posterior horn cell of the spinal cord and terminates in the superior corpora quadrigeminal body of the mid-brain and serves spino-visual reflexes.

Origin : Thie tract arises from the posterior horn cells of the spinal cord of the opposite side.

Situation : This tract is situated in the ventro-lateral region of white matter in the lateral column of the spinal cord, just infornt of the lateral spino-thalamic tract, being most prominent in the cervical region only.

Course, Extent and Termination : After arising from the posterior horn cells of the spinal cord of the opposite side this tract passes through medulla, pons, crus. substantia nigra, tegmentum, medial fillet and ends in the superior colliculus of the tectal part of the mid-brain.

Functions : The Spino-tectal tract carries impulses to superior colliculi of the mid-brain and provides a pathway for spino-visual reflexes, resulting in movements of head and eyes towards the source of stimulation.

Q. 12. Describe the Spino-thalamic Tract.

The Spino-thalamic tract arises from the posterior horn cells of the spinal cord and ends in the lateral or ventral nucleus of thd thalamus. The lateral Spino-thalamic tract carries Crude or Protopathic and Fine or Epicritic cutaneous non-kinaesthetic pain and temperature sensations. The Ventral Spino-thalamic tract carries crude and fine cutaneous non-kinaesthetic touch sensations.

Origin : This tract arises from the posterior horn cells of the spinal cord. The central process of the cells of the posterior root ganglion carrying sensation of pain, temperature and touch will enter the spinal cord through the posterior nerve root. The fibres of pain and temperature will relay in the cells of Substantia Gelatinosa Rolando.

Course, Extent and Crossing : (Fig. 20) The fibres of Spinothalamic tract cross obliquely in the posterior or anterior commissure to the opposite antero-lateral region of the white matter of the spinal cord and ascend to end in the thalamus. In the spinal cord the spino-thalamic tract consists of a posterior or lateral and an anterior or ventral part. They occupy the ventrolateral region of white matter.

(a) **Lateral Spino-thalamic Tract** : Many of the fibres of the lateral tract are non-myelinated. They ascend a short distance in Lissauer's tract and relay in the cells of the substantia Rolandi. The second order fibres originating in these cells, cross near the central canal to form the lateral spino-thalamic tract where they are dermatomally arranged, cervical nearer mid-line, sacral most lateral. In this way they ascend by the spinal lemniscus to the optic thalamus where those concerned with the cruder sensations end. Some others for less crude forms relay round third order cells in the thalamus, which convey the impulses to the cerebral cortex.

(b) **Ventral Spino-thalamic Tract** : The axons of posterior horn cells cross to the opposite side to form the ventral spino-thalamic tract, Some of them constitute in the dorsal column to reach nuclei gracilis and cuneatus where they end. The ventral spino-thalamic tract joins the spinal leminiscus and ascends to end in the thalamus. From there, third order fibres convey the impulses to the cerebral cortex.

Terminations : The fibres after relay in the lateral nucleus of the thalamus would be terterminated as follows :

(a) **Intra-Thalamic terminations** : Th fibres carrying protopathic part of touch and temperature sensations and all the pain fibres would terminate in the medial nucleus of thalamus. This medial nucleus acts as a higher centre for all crude sensations so it is known as essential organ of Thalamus.

(b) **Extra-Thalamic terminations** : After relay from the ventral nucleus, the fibres carrying epicritic part of touch and temperature sensation would pass through the posterior limb of the internal capsule to reach the sensory area of the cerebral cortex.

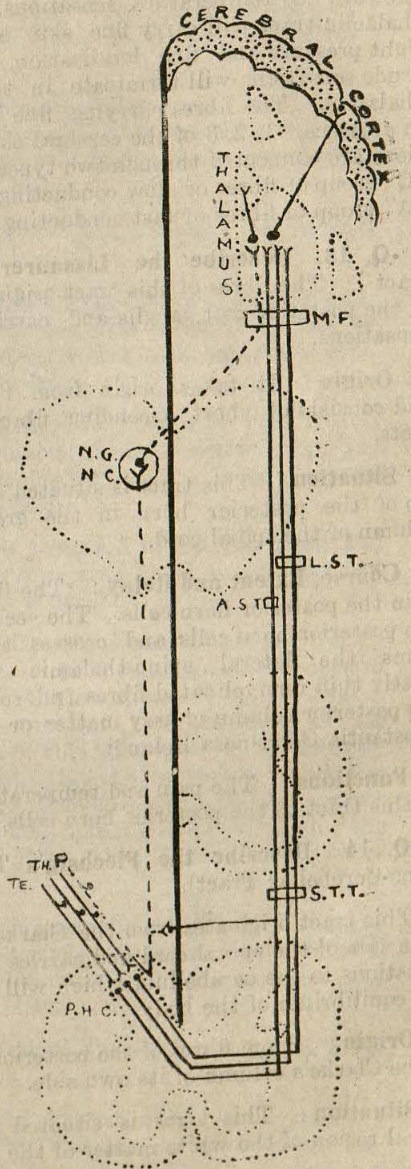


Fig. 20. Spino-thalamic Tracts. P—Pain, TH—Touch, TE—Temperature, P. H C—Porterior Horn Cells. S. T. T. Spino-Thalamic Tract, A. S, T Anterior Sqino-Thalamic Tract, L. S. T. Lateral Spino-Thalamic Tract, M. F. Medial Fillet, N G. Nucleus Gracilis, N. C. Nucleus Cuneatus.

Functions : (1) The lateral spino-thalamic tract will carry the pain and temperature sensations. (2) The ventral spino-thalamic tract will carry fine skin sensations like light touch, light pressure and fine localisation. (3) The fibres carrying crude sensations will terminate in the medial nucleus of the thalamus. The fibres carrying fine sensations will terminate in areas no. 1, 2, 3 of the cerebral cortex. (4) The pain sensations are connected through two types of fibres such as through "C" group of fibres or slow conducting nerve fibres and through "A" group of fibres or fast conducting nerve fibres.

Q. 13. Describe the Lissaurer's Tract (Postero-lateral tract). The fibres of this tract originate from the nerve cells of the posterior root ganglia and carries pain and temperature sensations.

Origin : It takes origin from the posterior root ganglia and consists of short ascending fibres of the posterior nerve roots.

Situation : This tract is situated at the outer side of the tip of the posterior horn in the grey matter of the lateral column of the spinal cord.

Course, Extent and Relay : The first neurone of this tract is in the posterior horn cells. The second neurone begins from the posterior horn cells and crosses to the opposite side and froms the lateral spino-thalamic tract. These fibres are mostly thin unmyelinated fibres and relay around the cells of the posterior column of grey matter or in certain cells in the Substantia Gelatinosa Rolandi.

Functions : The pain and temperature impulses are relayed by this tract to the posterior horn cells.

Q. 14. Describe the Flechsig's Tract (Direct or Dorsal Spino-Cerebellar Tract).

This tract originates from the Clarke's column cells of the same side of the spinal cord and carries unconscious kinaesthetic sensations to the cerebellum which will maintain tone, posture and equilibrium of the body.

Origin : Some fibres of the posterior root of this tract end in the Clarke's column of its own side.

Situation : This tract is situated on the surface of the lateral region of the white matter of the spinal cord.

Course, Termination and Relay : (Fig. 20.) This tract originates from the Clarke's column cells of the same side, run upwards and in the vermis of the cerebellum via the inferior cerebellar peduncle or restiform body. The third order neurone from vermis passes to the cerebellar cortex. Some of the axons from the Clarke's column cells cross to the spino-cerebellar tracts of the opposite side.

Functions : The dorsal spino-cerbellar tract will carry unconscious kinaesthetic sensations. It will maintain the tone of various muscles, co-ordinated contraction of the muscles and postures and equilibrium of the body.

Q. 15. **Describe the Gower's Tract** (Ventral or Indirect Spino-Cerebellar tract).

The fibres of this tract originate from Clarke's column cells of both sides and carries unconious kinaesthetic senstions to the cerebellum from both the sides which will maintain tone, posture and equilibrium of the body.

Origin : It arises from the Clarke's column of cells mainly of the same side and to some extent of the opposite side. The cross fibres of the Gower's tract may arise from cells scattered along the margin of the ventral horn.

Composition : This tract is composed of both crossed and uncrossed fibres. The presence of crossed fibres in an apparent violation of ipsilateral cerebellar control.

Course with Relay : (Fig. 20.) The fibres of this tract originate from Clarke's column cells of both sides and pass upward traversing the medulla and mid-brain and goes upto the level of the red nucles without any termination. At the level of the mid- brain the uncrossed fibres of this tract turn back abruptly and enter into the cerebellum via the superior cerebellar peduncle and end in the vermis. The crossed fibres again cross and enter the cerbellum of the opposite side through the superior cerebellar peduncle. From this, third order fibres travel to the cerebellar cortex.

Functions : The ventral spino-cerebellar tract will carry unconscious kinaesthetic sensations. It will maintain the tone of various muscles, co-ordinated contraction of the muscles and posture and equilibrium of the body.

Q. 16. **Describe the Pyramidal Tract** (Cortico-spinal Tract or Cerebro-spinal Fasciculus).

The pyramidal tract is the longest chief motor pathway starts from the cerebral cortex and reaches upto the last segment of the spinal cord and then to the voluntary muscle. It carries volitional impulses for the movement of the voluntary muscle. The fibres taking origin from the highest part of this area will crotrol the movements of the lowest part of the body and the fibres taking origin from the lowest part of this area, controls the movements of the highest part of the body.

Naming : The pyramidal tract is so named because : (1) It originates from the pyramid shaped cells of the cerebral cortex. (2) It crosses at the pyramid portion of the medulla oblongata. (3) In the white matter of cerebrum, it forms corona radiata which is a fan-shaped structure that looks like the shape of a pyramid and it is so named.

Types : The pyramidal tracts arise from pyramidal and Betz cells of the precentral gyrus. (1) The fibres arise from the motor area of the cerebral cortex and reaches to the anterior horn cells of the spinal cord which constitute the *cortico-spinal tract*. (2) The fibres arise from the Betz cells of the cerebral cortex and reach to different motor cranial nerve nuclei which constitute the *cortico-bulbar tract*.

I. Cortico-Spinal Tract : It arises from the pyramidal cells and Betz cells of the precentral gyrus and reaches to the anterior horn cells of the spinal cord.

Origin : The different sources of cortico-spinal tract are the following. (a) *Anatomical Origin* : This tract originates from the area no. 4 of the precentral gyrus which is situated at the anterior side of the fissure of Rolando. (b) *Histological Origin* : This tract originates from the Pyramidal and Betz cell which are situated in the giant pyramidal cell layer of the internal lamina of cerebral isocortex. (c) *Embryological Origin* : This tract originates from the neocerebrum.

Situation : The situation of the pyramidal tract is different depending on its different sites in the central nervous system.

(a) *In the Cerebral hemisphere* : This tract is situated in the (1) Corona radiata and (2) Internal capsule.

(b) *In the Mid-brain* : This tract is situated in the crus of the cerebral peduncle of the mid-brain.

(c) *In the Pons* : This tract is situated in the ventral aspect of the pons.

(d) *In the Medulla oblongata* : This tract is situated in the pyramid portion of the medulla oblongata.

(e) *In the Spinal Cord* : This tract is situated in the following columns : (1) Lateral white column—Crossed pyramidal tract is situated. (2) Anterior white column—Uucrossed pyramidal tract is situated. (3) Lateral white column—few uncrossed fibres descend in the same side.

Course with Relay : (Fig. 21) The discussion of the course with relay of this tract would be simple if its situation at different sites as follows :

(1) **In Corona Radiata** : This tract originates from the Pyramidal cell and Betz cell of the *Cerebral Cortex* and ascends in a fan shaped manner with the ascending fibres forming *corona radiata.* (2) **In the Internal Capsule** : The fibre reaches at the level of basal ganglia and then occupy the anterior 2/3rd of the posterior limb and a little portion of the anterior limb of the *Internal Capsule.* (3) **In the Mid-brain** : The pyramidal fibres descend as the cerebral peduncle and in the *mid-brain* they occupy the middle 3/5th of the crus. (4) **In the Pons** : These fibres become scattered and descend through the spaces between the nuclei of the pons. (5) **In the medulla oblongata** : The fibres come together and the bundle occupy the anterior most position causing a swelling known as *Pyramid.* In the pyramid portion of the medulla, each tract divides into two bundles of unequal sizes, the larger of which crosses with the corresponding bundle of the opposite side forming the *motor decussation* and decends in the posterior part of the spinal cord. This

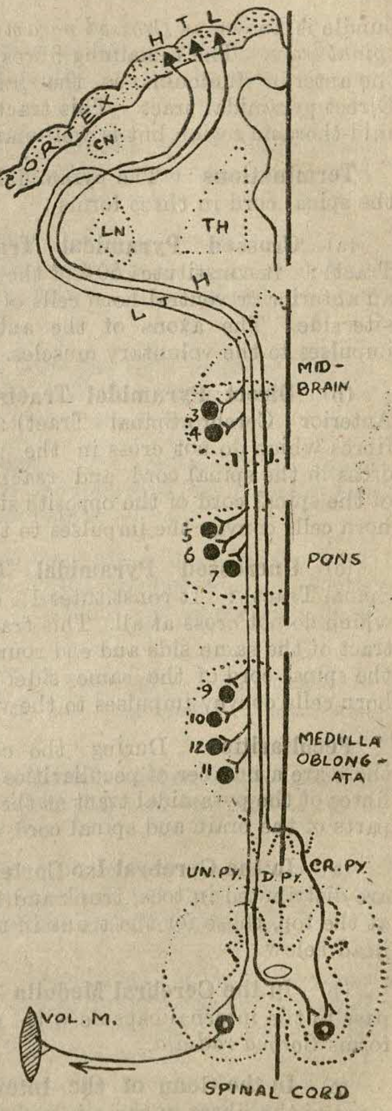


Fig. 21. Path of Pyramidal Tracts. Vol. M,—Voluntary Muscle, UN. Py—Uncrossed Pyramidal Tract, D. Py—Direct Pyramidal Tract, CR. Py—Crossed Pyramidal Tract, Motor Cranial Nuclei (3, 4, 5, 6, 7, 9, 10, 11, 12), L—Leg Fibres, T—Trunk Fibres, H—Head Fibres, C.N.—Caudate Nucleus, L.N.—Lentiform Nucleus, T.H—Thalamus.

bundle is known as *Crossed pyramidal tract* or *Lateral Cortico-spinal tract*. The remaining fibres are uncrossed and descend in the anterior funiculus as the *Anterior coritco-spinal tract* or Direct pyramidal tract. This tract scarcely found in below the mid-thoracic region but is well-marked in the cervical region.

Terminations : The pyramidal fibres end or terminate in the spinal cord in three forms :

(a) **Crossed Pyramidal Tracts** (Lateral Cerebro-Spinal Tract) : It constitutes 50% of the fibres which usually end at an anterior or ventral horn cells of the spinal cord of the opposite side. The axons of the anterior horn cells convey the impulses to the voluntary muscles.

(b) **Direct Pyramidal Tracts** (Anterior Cortico-Spinal or Anterior Cerebro-Spinal Tract) : It constitutes 49% of the fibres which do not cross in the pyramid of the medulla but cross in the spinal cord and reach at the anterior horn cells of the spinal cord of the opposite side. The axons of the anterior horn cells convey the impulses to the voluntary muscles.

(c) **Uncrossed Pyramidal Tracts** (Uncrossed Cerebro-Spinal Tract) : It constitutes 1% of the direct pyramidal tract which do not cross at all. This tract joins the crossed pyramidal tract of the same side and end round the anterior horn cells of the spinal cord of the same side. The axons of the anterior horn cells convey impulses to the voluntary muscles.

Peculiarities : During the course of cortico-spinal tract there are a number of peculiarities seen and disposition of the fibres of the pyramidal tract at the different sites of thedifferent parts of the brain and spinal cord which are the following :

(a) **In the Cerebral Iso-Cortex** : In this region, the fibres are distributed in toes, trunk and head. Those for the toes are at the top, those for the trunk in the middle and those for the head below.

(b) **In the Cerebral Medulla** : These fibres converge and pass to the internal capsule with a radiating arrangement and forms *Corona radiata*.

(c) **In the Genu of the Internal Capsule** : The arrangement of the fibres in the cerebral cortex become reverse at the genu of the internal capsule. The 'head' fibres now occupy the most anterior part, the 'leg' fibres occupy the most posterior part and the 'trunk' fibres remain in the middle.

(d) **In the Mid-brain** : The cortico-spinal fibre occupy in middle 3/5th of the crus of the mid-brain. The medial $\frac{1}{5}$th is occupied by the fronto-pontine and cortico-nuclear fibres and the lateral $\frac{1}{5}$th by the temporo-pontine fibres. The 'head' fibres remain medially, 'leg' fibres laterally and the 'trunk' fibres in the middle.

(e) **In the Pyramid portion of Medulla** : The distribution of the fibres at this region becomes 50% of the same side and 50% of the opposite side.

(f) **In the Spinal Cord :** The cortico-spinal fibres occupy 1% uncrossed fibre to the same side and 99% of the crossed fibre (crossed fibre 50% and direct fibre 49%) of the opposite side of the spinal cord.

Therefore, nearly all fibres from the right motor cortex are distributed to the left side of the body and lower hemisphere supplies the impulse of the right side of the body.

Branches and Distributions : The cortico-spinal tract during its descending course gives the following branches at the different regions of brain and brain-stem.

(a) **In the Cerebrum** : This tract gives fibres to the fusiform cell layer of the cerebral cortex, caudate nucleus, lentiform nucleus, internal capsule, thalamus and hypothalamus of cerebral medulla.

(b) **In the Mid-brain :** This tract gives collaterals to substantia nigra, red nucleus of the tegmentum, tegmental nuclei of the pons.

(c) **In the Pons** : This tract gives branches to the pontine nucleus, corpus trapezoidium and 5th, 6th and 7th cranial nerve nuclei of the pons.

(d) **In the Medulla** : This tract gives branches to the pyramid, nucleus gracilis and cuneatus and 9th, 10th, 11th and 12th motor cranial nerve nuclei of the medulla oblongata.

II **Cortico-bulbar Tracts** (Genicular or Cortico-nuclear Tracts) : This tract arises from the Pyramidal cell and Betz cell of the cerebral cortex. It passes through the genu of the internal capsule, mid-brain, pons and medulla and reaches to the motor cranial nerve nuclei such as 3rd and 4th cranial nuclei of mid-brain, 5th, 6th, 7th cranial nuclei of the pons and 9th, 10th, 11th and 12th motor cranial nuclei of medulla oblongata. *Kypers* in 1958 has indicated that in man some *corticifugal fibres* pass directly to the motor trigeminal, facial, hypoglossal and also supraspinal nuclei.

Functions : The corticobulbar tracts are essentially meant for volitional control of the muscles of the larynx, pharynx, palate, upper and lower face, jaw, eye, etc.

Functions of Pyramidal Tract: The pyramidal tract possesses the following functions: (1) It is a motor tract and concerned with co-ordinated movements of muscle which is concerned with voluntary or wilfully movement or volitional movement. (2) The pyramidal tract inhibits the tone of the muscles through the inhibition of anterior horn cells. (3) This tract is highly developed in higher animals. In the lower animal this tract is very rudimentary and it is much developed in case of man and higher apes. (4) This tract transmits the motor impulses to the voluntary muscles and also inhibits the muscle and spinal reflexes and possibly form a part of the pathway for superficial reflexes. (5) This tract supplies all the motor cranial nerve nuclei. The third one is for vision, nine and twelve nerves act as swallowing and movement of the tongue.

Q. 17. **Describe the Extra-Pyramidal System** (Old motor system).

The extra-pyramidal tracts are the descending motor pathways which originate from the lower motor centre of the brainstem. These are additional motor tracts, other than pyramidal tract that cortrol volitional impulses and are the following:

I. **Rubro-Spinal Tract** (Pre-Pyramidal Tract or Monakow's Bundle): This tract arises from the red nucleus of the midbrain and relays at the anterior horn cell of the spinal cord and it is so named. **Origin**: It originates from the nucleus *Magno-Cellularis* of the red nucleus of the mid-brain, which is situated below the third cranial nerve nuclei of the tegmentum. **Course with Relay**: (Fig. 22). The tract decussates immediately after their origin and this decussation is known as *Forel's decussation*. The tract then passes through pons, medulla and ultimately reaches the lateral column of the spinal cord from where they finally relay in the anterior horn cells. The fresh fibres from the anterior horn cells as motor fibres will supply the extensor muscles of the body. This fibres are found only upto mid-thoracic region. **Extent**: In human being, it may reach upto the mid-thoracic segment but in animal it will reach upto the last segment of the spinal cord. **Termination**: This tract terminates by giving connection to the anterior horn cells of the spinal cord. **Functions**: (1) This tract inhibits the tone of the extensor muscles of the body. Section of this tract will therefore increase the rigidity of muscle leading to a condition know as *Decerebrate rigidity*. (2) It is also concerned in labrynth and body righting reflexes.

II. **Tecto-Spinal Tract**: This tract arises from the tectal nucleus of the mid-brain and relays at the anterior horn cell of the spinal cord and it is so named. **Origin**: The fibres of this tract originates at the *superior corpora quadrigeminal bodies* which are situated at the tectal part of the mid-brain. **Course with Relay** : (Fig. 22). The tract crosses over the middle line to form decussation known as *Meynerts' tegmental decussation*. The tract passes through pons, medulla and reaches the anterior white column of the spinal cord from where they finally terminate in the anterior horn cells. The fresh fibres from anterior horn cells as motor fibres will supply the muscles of the body. These fibres are found only in the cervical region. **Extent**: This tract may reach upto the thoracic segment of the spinal cord. **Termination** : This tract terminates by giving connection to the anterior horn cells of the spinal cord. **Functions** : Through this tract, visual impulses are conveyed to the spinal cord which carry out the movements of the muscles by contraction. It is therefore responsible for visuo-spinal reflex.

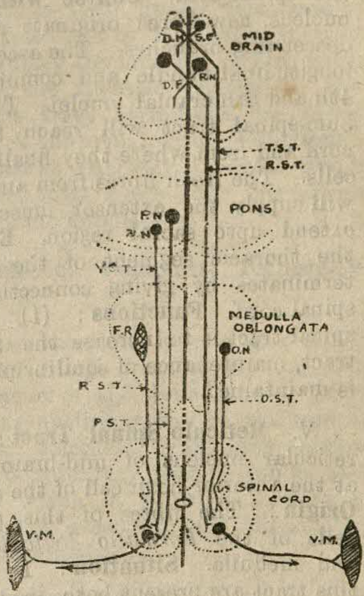


Fig. 22. Extra-Pyramidal Tracts, S.C—Superior Colliculus. D. M—Decussation of Meynert. R, N—Red Nucleus, D. F.—Decussation of Forel. P. N—Pontine Nucleus. D. N.—Deiter's Nucleus. F. R—Formatio Reticularis. O.N—Olivary Nucleus. T.S.T—Tecto-Spinal Tract. R.S.T Rubro-Spinal Tract, V. S. T—Vestibulo-Spinal Tract. R S. T—Reticulo-Spinal Tract. P. S. T—Ponto-Spinal Tract. O.S.T—Olivo-Spinal Tract.

III. **Ponto-Spinal Tract** : This tract arises from the pontine nucleus and relays at the anterior horn cell of the spinal cord and it is so named. **Origin** : It originates from the nuclei pontis which remain scattered in the upper regions of pons of both sides. **Course with Relay** : (Fig. 22) The fibres of this tract pass through pons, medulla and reaches the anterior horn cells of the spinal cord. The fresh fibres from anterior horn cells as motor fibres will supply the muscles of the body. These fibres are found only in the cervical region. **Function** : This tract is concerned with audito-spinal reflex and thereby it regulates tone, posture and equilibrium of the body.

IV. **Vestibulo-Spinal Tract** : This tract arises from the vestibular nucleus of the pons and relays at the anterior horn cell of the spinal cord and is so named. **Origin** : The fibres of this tract originate from the *Dieter's nucleus* or *lateral vestibular* *nucleus* situated in the pons. **Situation**: The fibres of this tract are present both in the lateral and anterior white column of the spinal cord. **Course with Relay**: (Fig. 22) From this nucleus, new fibres originate and divided into ascending and descending branches. The ascending branch form the posterior longitudinal bundle and communicate with red nucleus, 3rd, 4th and 6th cranial nuclei. The descending branch as vestibulo-spinal tract will reach the lateral column of the spinal cord and from where they finally terminate in the anterior horn cells. The fresh fibres from anterior horn cells as motor fibres will supply the extensor muscles of the body. These fibres extend upto sacral region. **Extent**: This tract extends upto the thoracic segment of the spinal cord. **Termination**: It terminates by giving connection to anterior horn cells of the spinal cord. **Functions**: (1) The function of the vestibulo-spinal tract is to increase the muscle tone. (2) Through this tract, maintenance of equilibrium i.e. position of trunk and limb is maintained.

V. **Reticulo-Spinal Tract**: This tract arises from the reticular nucleus of mid-brain, pons and medulla and relays at the anterior horn cell of the spinal cord and it is so named. **Origin**: The fibres of this tract orginate from the nerve cells of the *Formatio Reticularis* of the mid-brain, pons and medulla. **Situation**: In the spinal cord, the fibres of this tract are present both in the lateral and anterior white column. **Course with Relay**: (Fig. 22) The tract passes through the medulla and reaches the anterior white column of the spinal cord from where they terminate finally in the anterior horn cells. The fresh fibres from the anterior horn cells as motor fibres will supply the muscles of the body. These fibres are probably found throughout the whole length of the spinal cord. **Extent**: This tract may reach upto the thoracic segment of the spinal cord. **Termination**: This tract terminates by giving connection to the anterior horn cells of the spinal cord. **Functions**: (1) The function of this tract is to increase or decrease the activity of the lower motor neurone. (2) This tract therefore may increase or decrease the tone of the muscles of the body whenever necessary to maintain the posture and equilibrium of the body. (3) It maintains the regulation of posture of the body.

VI. **Olivo-Spinal Tract**: (Bulbo-spinal Tract or Tract of Helweg): This tract arises from the olivary nucleus of the medulla oblongata and relays at the anterior horn cells of the spinal cord and it is so named. **Origin**: The fibres of this tract originate from the inferior olivary nucleus of the medulla oblongata which is originated from the cervical region only. **Situation**: This tract is situated in the lateral white column of the spinal cord. **Course with Relay** : (Fig. 22) The fibres pass through the medulla and reach the anterior white column of the spinal cord from where they finally terminate in the anterior horn cells. The fresh fibres from the anterior horn cells are motor fibres will supply the muscles of the body. **Extent** : This tract reaches upto the thoracic segment of the spinal cord. **Termination** : This tract terminates by giving connection to anterior horn cells of the spinal cord. **Functions** : This tract constitutes an important pathway through which impulses from cortex and thalamus may reach into the spinal cord helping transmission of thalamic impulses.

Q. 18. Describe the effects of Complete Transverse Section of Spinal Cord.

A sudden or rapidly progressive, complete interruption of the continuity of the spinal cord may result from injury such as gun-shot wound, fracture, dislocation of the spine etc. or from acute inflammation e.g. transverse myelitis or can be produced in an experimental animal. After complete transverse section of the spinal cord, complete loss of voluntary power results and paralysis of both limbs occur which is known as paraplegia. These disorders are due to cutting of ascending and descending tracts carrying sensory and motor impulses.

Causes : The complete transverse section of spinal cord may take place due to : (a) Accidental injury such as gun shot, fracture and dislocation of spine etc. (b) Acute inflammtory disease like Transverse myelitis.

Results After Complete Section of Spinal Cord :

(a) **Below the Level of Lesion** : (1) Complete paralysis of the upper motor neurone type i.e. permanent loss of the voluntary movement of all the muscles on both sides. (2) Complete anaesthesia such as complete loss of all true sensation in different parts of the body on both sides. No sensation reaches towards the higher centre. (3) Reflexes such as micturition and defaecation become automatic after a period of paralysis. (4) Temporary vaso-dilatation causes accumulation of blood within the blood vessel. (5) Tropic disturbances such as the skin will become shiny and bed sores occur.

(b) **At the Level of Lesion** : (1) Complete anaesthesia on both sides. (2) Complete paralysis of the lower motor neurone type on both sides. (3) Temporary vaso-motor paralysis on both sides.

(c) **Above the Level of Lesion** : A band of hyreraesthesia all round the body on both sides.

Stages After Complete Section of Spinal Cord : The subsequent history of the subject of a complete transverse spinal lesion has been divided into following stages by *Riddock*.

I. **First Stage or Stage of Spinal Shock (Stage of Flaccidity)** : There is to start with a condition of shock which is called '*Spinal Shock*'. The manifestations are: (1) Complete loss of visceral and somatic sensations of all types below the site of lesion. (2) The muscles become flaccid. (3) The skeletal muscles are quite toneless. (4) The tendon jerks, planter response and abdominal reflexes are abolished. (5) The cremasteric and bulbocavernosus reflexes though absent as a rule, may at times be elicited. (6) Hyperaesthesia is immediately caused. (7) Spontaneous pain or a feeling of tightness encircling the body may be experienced by the patient. (8) The bladder and the rectum are paralysed and the anal and vesical sphincters are tightly contracted, leading to retention of faeces and urine. (9) The penis is flaccid and its erection is impossible. (10) The portion below the site of section shows absolute coldness followed by gradual return to warm as the local control over vascular supply is established. (11) The subject may be concious or unconscious.

II. **Second Stage or Stage of Reflex activity or Stage of Recovery** (Paraplegia in flexion) : The manifestations are : The flexor muscles gradually regain a part of their lost tone. (2) The first reflex to appear is the so-called extensor response or sign of Babinski. (3) The tone of the extensor muscles is restored to some extent and the tendon jerks reappear. (4) The knee-jerk returns usually in from 3 to 7 weeks after the injury. (5) The ankle jerks are weak or may not appear at all. (6) Clonus is very rarely obtainable. (7) The functional activity returns first in smooth muscle and as a result, the muscle of urinary bladder recover partially. Blood pressure may be restored to normal level. (8) The tone of the voluntary muscle recover as a result of, there will spastic type of paralysis and increased deep reflexes but below the level of section, there will be lower motor neurone type of lesion due to the destruction of anterior horn cells. (9) The person can control the micturition reflexes partly but also there may be retension of urine.

III. **Third Stage or Stage of Hyperactivity** : The manifestations are : (1) A flexor spasm of the muscles of the abdominal wall and lower extremities as a result of stimulation of the skin of the abdomen, genital region or limbs. (2) The sweating is caused by the stimulation of the skin or of the visceral or rectal mucosae, its distribution is roughly, that of the sensory loss. (3) Evacuation of the bladder, even though only partially filled, and of the rectum follows stimulation of the skin or of the respective mucous surface.

IV. **Fourth Stage or Stage of Failure of Reflex Activity :** The features would be as follows : (1) All the reflexes are gradually diminished and ultimately there will be complete abolition of all the muscle reflexes. (2) The bladder tone is lost. The rectum is paralysed and there will be involuntary expulsion of urine and faeces. (3) The inter-urethral sphincter will loss its function and as a result, there will be retention of urine and faeces occurs or there may be continual dribbling of urine and faecal matter is incontinence. (4) Degeneration of the cells of the spinal grey matter. (5) There will be ulcers on the skin and the patient may die due to infection. (6) Mass reflex disappears. (7) The withdrawal reflex function occurs. (8) The failure of reflex function occurs and to elicite a reflex, maximum stimulus may be required. In this stage, the subject usually dies if infection is severe.

Q. 19. Describe the effects of Hemisection of Spinal Cord (Brown Sequard Syndrome).

The term 'Hemisection' is generally used to indicate a lesion involving one lateral half of the spinal cord i.e., from white matter to the central canal. This may be done experimentally or it may be produced due to accidents, such as gun-shot injury. The effects which are produced, are collectively called the *Brown Sequard Syndrome*. It is based entirely on the results of clinical observations and it is customary to assume that the lesion is of gradual development and not of acute onset. The symptoms that follow division of the right or left side of the spinal cord were first described by *Brown Sequard*, a French physician and after a preliminary period of spinal shock, the different peculiar phenomenon are caused.

Manifestations after Hemisection of Spinal Cord : The changes occur after hemisection of spinal cord would be as follows :

I. **Below the Level of Section** :

A. **Same side :** (a) **Sensory changes** : (1) Loss of conscious muscle-sense or kinaesthetic sensations, sense of vibration, lactile localisation and discrimination. (2) No loss of pain, touch and temperature sensation. (3) Ataxia is caused due to the section of spino-cerebellertracts. (b) **Motor Changes :** (1) There will *be upper motor neurone type of lesion* due to the section of pyramidal tract to be manifested by the following : (i) The limb is extended at the hip, knee and ankle with the toes pointing slightly downwards. (ii) There is spasticity of the affected muscles due to increased postural tone which is detected by knee-jerk. (iii) There is no atrophy of muscles except after prolonged disuse. (iv) The reaction of reflex degeneration is absent. (v) Deep reflexes such as knee-jerks and ankle-jerks are exaggerated. (vi) Superficial reflexes are absent. (vii) Babinski's signs are present. (viii) Ankle clonus and patellar clonus are present. (2) Temporary vaso-motor paralysis.

B. **Opposite side** : (a) **Sensory changes** : (1) No loss of deep sensations, fine touch, tactile localisation and tactile discrimination as the tracts of Goll and Burdach are intact. (2) Loss of pain and temperature due to the section of spino-thalamic tract but touch sensation will persist. (b) **Motor changes** : No paralysis will occur in the upper motor neurone type. (c) **Vaso-motor changes** : There will be no change at all.

II. At the Level of Section.

A. **Same Side** : (a) **Sensory changes** : (1) Loss of deep sensations, tactile localisation, tactile discrimination and fine touch. (2) Loss of pain, touch and temperature. (3) Loss of reflex action and the reflex arc will be destroyed. (4) Ataxia is caused due to section of spino-cerebellar tract. (b) **Motor changes** : (1) There will be *lower motor neurone type of lesion* due to the destruction of anterior horn cells to be manifested by the following : (i) Loss of muscle power. (ii) Loss of muscle tone. (iii) Wasted of the affected muscle due to loss of all activities including reflex activity. (iv) Flaccid type of paralysis. (v) Both superficial and deep reflexes are absent. (vi) Babniski's sign is absent. (vii) Reaction of degeneration appears after some time. (a) No response with Faradic current. (b) A slow wave-like contraction with Galvanic current. (c) Anode closing contraction (A.C.C) is greater than Cathode closing contraction (K.C.C) (2) Complete and permanent vaso-motor paralysis. Sweating stops, making the skin dry. (3) Trophic lesions, such as ulcers, bed-sores, witlows and Charcot's joints, may develop due to loss of protective pain sensibility.

B. **Opposite side** : (a) **Sensory changes** : (1) Loss of pain, touch and temperature due to section of spino-thalamic tract. (2) No disturbance of posture and equilibrium. (3) No loss of deep sensation, fine touch tactile localisation and tactile discrimination. (b) **Motor changes** : There will be no change or change may be slight. (c) **Vaso-motor changes** : Not occur at all.

III. Above the Level of Section :

A. **Same side** : (1) Due to the irritation of the cut sensory fibres, immediately above the level of section, there will be a zone of hyperasesthesia in the skin area corresponding to the peripheral distribution of the posterior nerve root entering the spinal cord. (2) A very mild painful stimulus will produce severe pain sensations in the body.

B. Opposite side : There will be hyperaesthesia may extent all over the body.

Q. 20. What do you understand by upper and lower motor neurone ? Compare upper motor neurone paralysis with the paralysis due to lesion of the lower motor neurone.

The *upper motor neurone* is a neurone which starts from cells in the higher centre i.e., the pyramidal cells and Betz Cells of the cerebral iso-cortex and ends at the anterior horn cells of the spinal cord or its cranial homologue as a cortico-spinal fibre. The other type of motor neurone is genicular fibre which starts from the pyramidal cells and ends in different motor cranial nerve nuclei of the brain-stem.

The *lower motor neurone* is a neurone which starts from the end of the upper motor neurone, may be situated either in the anterior horn cells of the spinal cord or in different motor cranial nerve nuclei which supply only to their respective effector organs. The lower motor neurone terminates in the muscles in a knob-like structure what is called motor end-plate.

The *upper motor neurone type of paralysis* is caused due to the lesion of pyramidal tract or pyramidal cells. The *lower motor neurone type of paralysis* is caused due to the destruction of anterior horn cells of the spinal cord or motor cranial nerve nuclei of the brain-stem or fibres arising from there.

Manifestations of Upper and Lower Motor Neurone type of Paralysis :

Lower Motor Neurone Lesion : (Nuclear & Infranuclear Type)	**Upper Motor Neurone Lesion** : (Supranuclear Type)
When the lower motor neurone is sectioned, there will be the following manifestations as for example :	The section of the upper motor neurone will produce the following manifestations as for example :
(1) **Complete Paralysis** : Loss of muscular power due to the damage or paralysis of single or many groups of muscles. There will be flaccid type of paralysis.	(1) **Complete Paralysis** : Loss of all kinds of muscular power and voluntary movement due to the paralysis of many groups of muscles and no paralysis of individual muscle. There will be rigid type of paralysis.
(2) **Hypotonus :** There is flaccidity of the muscles due to loss of muscle tone.	(2) **Hypertonus :** There is spasticity of the muscles due to increased muscle tone by the unchecked activity of extra-pyramidal tracts.

Lower Motor Neurone Lesion : (Nuclear & Infranuclear Type)	**Upper Motur Neurone Lesion :** (Supranuclear Type)
(3) **Atrophy :** The wastage of the muscle is marked due to loss of all activities. There may be tenderness and cramps in degenerating muscle.	(3) **Atrophy :** The wastage of muscle proper is absent except after prolonged disuse.
(4) **Reaction of Degeneration** : It appears after some time. As there is atrophy of the muscle, reaction of degeneration becomes positive. **(i)** No response to the Faradic current. **(ii)** A slow, worm like contraction to the Galvanic current. **(iii)** A.C.C. (Anodal closing contraction) is greater than K.C.C. (Kathodal closing contraction).	(4) **Reaction of Degeneration** Certain electrical discharge is absent. As the muscle tone is not lost as there is no atrophy of the muscles, reaction of degeneration is absent.
(5) **Reflexes :** These are all abolished due to interruption of the reflex arc. Plantar reflex if present, is of flexor type. Babinski's sign will be negative.	(5) **Reflexes :** (a) *Deep or Tendon Reflexes* : All the deep reflexes are increased. The knee-jerks and ankle jerks are exagerrated. (b) *Superficial* or *Cutaneous Reflexes* : These reflexes are lost or abolished. (c) *Babinski's sign* : It is present and this is extensor type of plantar response in normal healthy condition. In upper motor neurone type of lesion, when the stimulus is given to the sole of the foot, there will be dorsiflexion of the great toe and fanning of the other toes i.e. Babinski's sign is positive.
(6) **Ankle-clonus** : It is absent.	(6) **Ankle-clonus :** It is present.
(7) **Urine and Faeces** : The urine and faeces are in incontinence.	(7) **Urine and faeces** : The retention of urine and faeces is common.
(8) **Vaso-motor Paralysis** : It is complete and permanent which is due to the destruction	(8) **Vaso-motor Paralysis** : It is temporary which is caused due to the damage of the fibres

Lower Motor Neurone Lesion :	**Upper Motor Neurone Lesion :**
of sympathetic vaso-constrictor fibres. Sweating stops, skin is dry, cold and blue. Blood pressure may be low.	coming down to the lateral horn cells from the vaso-motor centre in the medulla oblongata.
(9) **Trophic Lesion** : It is developed and bed sores occur.	(9) **Trophic Lesion** : It is absent.
(10) **Twitchings or Fibrillation** : The fascicular twitchings of muscles or a fine flickering fibrillation may be present.	(10) **Twitchings or Fibrillation** : It is absent.
(11) **Muscular Contractures** : It leads to permanent shortening of the muscles.	(11) **Muscular Contractures** : It tends to develop in the spastic muscles.

Q. 21. What are the components of anterior nerve root ? What are the effects of anterior nerve root ?

The anterior nerve root possesses two components which are :

(1) *Somatic Motor fibre* : The nerve fibres coming from anterior horn cells which are supplied to the voluntary muscles.

(2) *Autonomic Motor fibre* : The fibres coming from lateral horn cells which are ultimately supplied to involuntary structures of the body i.e. glands, smooth muscles and blood vessels, etc.

Effects of Section : The effects of section of the anterior nerve root are grouped into structural and functional changes :

(a) **Structural Changes** : (1) There will be degeneration of the peripheral portion of the anterior nerve root. (2) The white rami dengeneration communicates upto the sympathetic ganglion. (3) There will be chromatolysis of the anterior and lateral horn cells.

Effects of Section : The effects of section of the anterior nerve root are grouped into structural and functional changes :

(b) **Functional Changes** : (1) Lower motor neurone type of paralysis to those muscles which are supplied by the anterior nerve root leading to : (i) Flaccid type of of paralysis of the affected muscles, (ii) Loss of reflexes, (iii) Wasting of the muscles, (iv) Reaction of degeneration present and (v) Sympathetic paralysis. (2)Changes in the vasomotor tone leading to dilatation of the blood vessels on the affected area.

Q. 22. What are the components of the posterior nerve root ? What are the effects of section of posterior nerve root ?

The posterior nerve root possesses the following components which are :

(1) *Somatic Sensory fibres* : These fibres carrying general sensations such as pain, touch, temperature, etc.

(2) *Viscero-Sensory fibres* : These fibres carrying sensation from the different visceras of the body.

(3) *Antidromic fibres* : These fibres are exactly not present proximal to the cells of posterior root ganglia but these are present particularly distal to the cells of posterior root ganglion. So exactly speaking, these fibres should not be included in the posterior nerve root. These fibrs are responsible for axon reflex.

Effects of Section : The effects of section of the posterior nerve root are grouped into following changes.

I. *Section Distal to the posterior root ganglion* :

(a) **Structural Changes** : (1) There will be Wallerian degeneration of the distal cut segments upto the receptors. (2) There will be chromatolysis of the cell of of the posterior root ganglion.

(b) **Functional Chages** : (1) Loss of deep sensations, fine touch, tactile discrimination and tactile localisation due to the section of the sensory nerves which will carry all these sensations. (2) Loss of pain, crude touch and temperature sensations due to the section of the sensory nerves which will carry all these sensations. (3) Loss of posture and equilibrium due to the section of the sensory nerves which will carry non-conscious kinaesthetic sensation. (4) Loss of superficial and deep reflexes due to the section of afferent neurones of the reflex arcs. (5) Loss of tone of the muscles due to the section of the reflex arc which reflexly maintain the tone of the muscles.

II. *Section Proximal to the posterior root ganglion* :

(a) **Structural Changes** : (1) There will be Wallerian degeneration of the distal cut segment upto tne next relay station. (2) There will be chromatolysis of the cells of the posterior root ganglion. (3) There will be chromatolysis of the cells of the next relay station which is called transneural degeneration.

(b) **Functional Changes** : (1) Loss of deep sensations, fine touch, tactile localisation and tactile discrimination. (2) Loss of pain, crude touch and temperature sensations. (3) Loss of posture and equilibrium. (4) Loss of superficial and deep reflexes. (5) Loss of tone of the muscles.

Q. 23. Write a critical essay on Conditioned Reflex.

A conditioned reflex is an acquired reflex, where the cerebral cortex is essential and where training and experience form the basis for the development of reflex process. *Pavlov* introduced a method of investigating the functions of the higher centres, which is capable of very wide applications.

Types of Reflexes : According to Pavlov, all reflex activities can be divided into two distinct classes :

(a) *Inborn or Uncoditioned reflex* : It is present from the birth and this refex is controlled by the centre situated in the spinal cord or in any other part of the central nervous system with the exception of cerebral cortex.

(b) *Acquired or Conditioned reflex* : It is not persent from the birth, but is acquired during life time by training or by education. The centre of this reflex is always situated in the cerebral cortex.

Types of Conditioned Reflex : There are two types of conditioned reflexes known as Positive or Excitatory conditioned reflex and Negative or Inhibitory conditioned reflex.

I. **Positive or Excitatory conditioned Reflex** : It comprises of Conditioned alimentary reflex, conditioned defence reflexes, Trace conditioned reflexes and Secondary and Tertiary conditioned reflex.

II. **Negative or Inhibitory Conditioned Reflex** :

(a) *External Inhibition* : These are temporary and permanent.

(b) *Internal Inhibition* : These are : (1) Differential inhibition. (2) Eztinction by inhibition. (3) Conditioned inhibition. (4) Inhibition of delay.

Characteristics or Laws or Properties ofConditioned Reflexes :

(a) **Specificity** : A conditioned reflex is established by a tuning fork of 1,000 vibrations per second. When a tuning fork of 500 vibrations per second is applied, there will be secretion of saliva but the quantity is less.

(b) **Summation** : The amount of saliva secretes by two conditioned stimuli is always double the amount obtained by a single conditioned stimulus.

(c) **Irradiation** : A conditioned reflex i.e., salivation is established by stimulating a particular area of the skin. If now an area close to orginal area is stimulated, there will be reflex secretion of saliva but the quality is small. This is due to the irradiation of impulses from one area to the other.

(d) **Inhibition** : There are two types of inhibition such as Extenal and Internal inhibition.

Functions of Conditioned Reflex : (1) They play very important part in the secretion of digestive juices such as secretion of saliva, gastric juices etc. (2) They regulate the behaviour and activity of the individuals or animals, so that they may properly adjust themselves to their surroundings. (3) According to *Pavlov*, sleep is due to a conditioned reflex and it is due to the process of internal inhibition which inhibits the functions of cerebral cortex. (4) Most of our habits are conditioned reflexes. (5) It has got an important value in clinical and psychological medicine (6) The drugs can affect the conditioned reflexes. Caffine and strychnine increase the effect of positive conditioned reflex whereas bromide increases internal inhibition.

Q. 24. What is Knee.Jerk ? What do you know about it ?

The knee-jerk or patellar jerk, a modified tendon reflex, is a fractionated stretch reflex or phasic deep stretch reflex. It is a forward jerk of the foot due to contraction of the vastus medialis and intermedius, when a light tap is struck upon the patellar ligament just below the knee, with the quadriceps put under some tension by flexion of the knee. It provides a very important diagnostic sign in diseases of the spinal cord.

Elicitation : When a sharp tap is struck upon the patellar tendon, but the knee joint is semi-flexed and the leg dependent, it causes a short twitch of the knee extensors i.e., vasti muscles. A voluntary action such as the clasping the hands together, reinforces the reflex and increases the jerk. To elicit this jerk, the patient is made to sit on the edge of a bed with one leg crossing over the other and hanging freely.

Cause : The brief contraction or jerk is not due to stimulation of the muscle. For a long time the knee-jerk was thought to be a direct response of the muscle to mechanical stimulation and not a reflex, since its latent period was too short. i.e., the time from the application of the tap to the response by visible contraction.

Knee-Jerk Reflex Path : The reflex are of knee-ierk consists of : The *receptor* is situated in the patellar tendon the *afferent impulses* from this tendon will go to the 2nd and 3rd lumbar segments which are the *centres* for this reflex. The *afferent-fibres* arise from the anterior horn cells of the 2nd and 3rd lumbar segments will come out through the anterior nerve root and will supply the quadriceps muscles which are *effector Organ.*

Physiological Value : Its great clinical value lies the fact that it is a very delicate physiological indicator of the tone of the nerve centres in general and those of the spinal cord in particular.

Q. 25. Describe the structure and functions of the Cerberum.

Brain, the most highly developed organ of the human being, composed of fore-brain, mid-brain and hind-brain. Cerebrum is one of the part of the fore-brain and consists of outer cortex and inner medulla. The adult cortex is made up of the outer palaeo *Allocortex* (1/12th part) comprising olfactory area only and the inner neo *Isocortex* (11/12th part) including the rest of the cortex.

I. **Structure of the Cerebral Cortex :** The structure of the different layers of the cerebral cortex are discussed below :

A. **Structure of the Allocortex :** It comprises 1/12 th part of the whole cerebral cortex. It is an old primitive cortex which has got three zones namely *Uncus* or *pyriform lobe*, *Dentate grrus* and the *Hippocampus*.

B. **Layers of the Isocortex :** The Isocortex is practically the main bulk of the cerebral cortex in human being. It is a modern cortex which comprises 11/12th part. From outside inwards the six layers of cerebral isocortex are discussed as follows :

(1) **Plexiform or Mononuclear Layer :** It is the outer most layer of the cerebral isocortex. It consists of : (i) Neurogeal cell. (ii) A few horizontal cell of Cajal. The cells are less densely placed but the transverse fibres are very dense. (iii) Numerous dendrites belonging to deeper layers.

(2) **External or Outer Granular Layer :** It is the second layer of the Cerebral isocortex which consists of : (i) Small densely packed granular cells which are round, polygonal or triangular in shape. (ii) Numerous dendritic processes of granular cells and small pyramidal cell. (ii) Neurogleal cells are also present. (iv) Transverse fibres are less densely placed.

(3) **External Pyramidal or Small Pyramidal Cell Layer :** It is the third layer which consists of : (i) Large and well formed small pyramidal cell, usually increase in size from without inwards. (ii) Its axon goes downwards and dendrites goes upwards upto upper two layers. (iii) Transverse fibses are less densely placed.

(4) **Internal Granular Layer :** It is the fourth layer of the cerebral cortex which is made up of two zonal layers.

(*a*) *Extra-Pyramidal Cell Layer* : It is the outermost layer which consists of : (i) Presence of star- shaped pyramids or Extra-Pyramidal cell. (ii) Presence of outer line of *Baillarger fibres*.

(*b*) *Stellate Cell Layer* (or Granular Layer or Middle Stellate Layer) : It is the innermost layer which contains : (i) A dense mass of stellate cells. (ii) Their axons are short and terminate in the same layer or in the pyramidal layer.

(5) **Internal Pyramidal Layer :** (Ganglionic Cell Layer) : It is the fifth layer which consists of *outer Giant Pyramidal Cell Layer* and *inner Betz Celll layer*.

(6) **Fusiform Cell Layer** : (Polymorphous Layer) : It is the sixth and the last layer of the cerebral iso-cortex which consists of : (i) Spindle shaped fusiform cell. (ii) Dendrites are present at both the sides of the fusiform cell. (iii) There are also few pyramidal shaped cells, known as cells of Martinotti (iv) Transverse fibres are densely placed.

II. **Structure of the Cerebral Medulla** : The medullary part of the cerebrum consists of nerve fibres and a patch of grey matter.

(a) **Nerve Fibres** : The white matter of the cerebrum is made up of three types of nerve fibres which are known as *Projection fibres, association fibres and commissural fibres.*

(b) **Patch of Grey matter** : The medullary part of the cerebrum contains a group of nuclei which are deeply situated within the patch of grey matter of the cerebrum and are known as deep nuclei of cerebrum. They are Thalamus, Hypothalamus, Corpus striatum comprising of caudate nucleus and lentifrom nucleus, Body of Luys, Claustrum and Amygdaloid nucleus, etc.

Functions of Cerebral Cortex :

(*a*) *Functions of the Allocortex* : (1) The uncus and hippocampal regions are concerned with smell sensation. (2) The dentate gyrus is concerned with taste sensation.

(*b*) *Functions of the Isocortex* : (1) The inner layer is concerned with organic and instinctive faculties. (2) The middle pyramidal layer receives afferent impulses and convert them to efferent one. (3) The outer layers are concerned with associated faculties and intelligence. (4) The granular layers are concerned with sensory and associative in function and deal with the reception and appreciation of the different sensory impulses. (5) The fusiform cell layer is concerned with instinctive activities such as feeding, excretion, etc.

Functions of Cerebral Medulla : The medulla is situated in the central part of the cerebrum comprising following functions :

(1) The nerve fibres constituting projection fibres, association fibres and commissural fibres perform the transmission of motor impulses to the lower part of the central nervous system and different lobes of the cerebral cortex.

(2) The commissural fibres form corpus callosum which strongly fixed up the two cerebral hemispheres side by side.

(3) The deep nuclei of cerebrum perform inter-communicating functions and serve as an association with their relative neighbouring structures.

Q. 26. What is Localisation ? How can you localise the different Centres and Functional areas in the Cerebral Cortex?

The localisation is a process by means of which one can locate the different centres and areas which are plotted specially on the cerebral cortex. From the different areas and centres of the cerebral cortex, one can know the different varieties of the functions of the cerebrum.

Methods for Localising Cerebral Centres : The function and situation of the different areas of the cerebral cortex have been revealed by the study of the results of several methods such as results of experimental removal, study of electro - encephalogram, ablation method, method of stimulation, histological method, embryologial method, etc.

Areas and Centres in the Cerebral Cortex : With the help of above methods, nearly a good number of areas have been mapped out in the cerebral cortex. The functions of the chief of the areas of pre-dominant functions and their relations to the areas on the structural map are briefly as follows :

I. **Frontal Lobe** : It comprises only motor and association areas. This lobe possesses areas 4, 6, 8—12, 44, 45, etc.

[A] **Motor Areas** : These comprise of areas 4, 6, 8, 44, 45 etc.

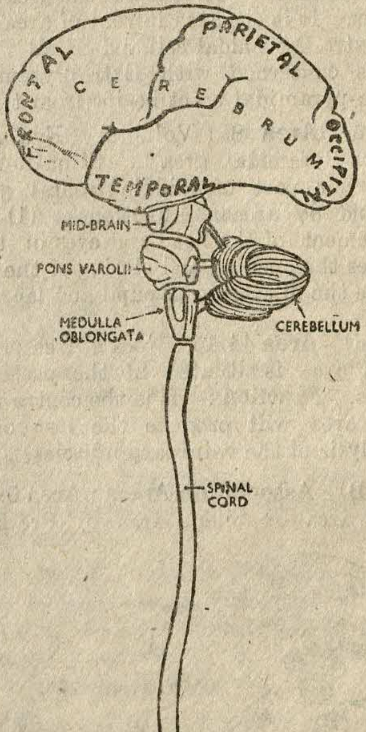


Fig. 23. Diagrammatic view of Brain and Spinal Cord showing different lobes of cerebrum.

(*a*) **Area** 4 (Pyramidal or Excito-motor Area). **Situation** : This area is situated at the anterior region of the fissure of Rolando or Pre-central gyrus of the cerebral cortex. This area is composed of Giant pyramidal cell and Betz cells. **Functions** : (1) The origin of the Pyramidal tract which is concerned with voluntary movement of the opposite side of the body. The centre for the various parts of the body are arranged from downwards to upwards such as toes, foot, leg, thigh, abdomen, thorax, shoulder, arm, hand, fingers, thumb, neck, face (ear, eye, lids, nose, tongue, palate), larynx. (2) It is responsible for non-postural, volitional skillful movement of the muscles of contralateral side.

(*b*) **Area** 6 (Pre-motor Area or Extra-Pyramidal Area) :

Situation : It occupies the greater part of the pre-central gyrus. It is situated infront of area 4. This area is composed of Extra-Pyramidal cell and Small Pyramidal cell. **Functions** : It is concerned with Extra-Pyramidal system and origin of extra-pyramidal tract begins from this centre.

(c) **Area** 8 (Voluntary Eye movement area or Largely Extra-Pyramidal area) : **Situation** : It is situated in the posterior part of middle frontal gyrus. It is composed of 8α, 8β and 8γ areas. Functions : (1) It controls the conjugate movement of the head and eyes of the opposite sides. (2) It serves the opening and closing of the eyelids. (3) It sometimes helps the dilatation of pupil and lacrymation.

(d) **Area** 44-45 (Broca's Area or Speech Area) : **Situation** : This area is situated in the posterior part of inferior frontal gyrus. **Function** : It is the centre for speech. The damage of this area will produce the loss of power of speech without paralysis of the voluntary muscles.

(B) **Association Areas** : **Area** 9-12 (Touch area or Intelligent area or Silent area or Pre-Frontal area or Association area) : **Situation** : It is situated in the anterior part of the frontal lobe. **Functions** : (1) It is the seat of intelligence. (2) The total removal of this area shows the person as an ediot. (3) These areas will control memory, intelligence, personality, sense of pleasure and humanity, etc. in intellectual activities.

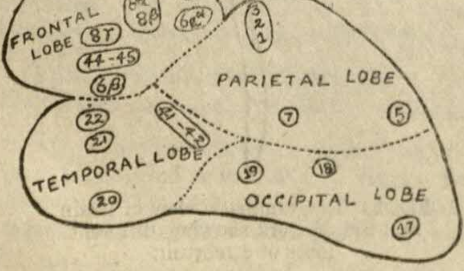


Fig. 24. Centres and Areas of the Cerebral Iso-Cortex.

II. **Parietal Lobe** : It comprises only sensory and association areas. This lobe possesses areas 3, 1, 2, 5 and 7.

(A) **Sensory Areas**: **Areas** 3,2,1 (Sensory area or Somesthetic area) ; **Situation**: It is situated at the posterior wall of the fissure of Rolando and post-central gyrus of the crebral cortex. **Functions**: (1) It is concerned with the appreciation of special senses such as vision, audition, taste and smell. (2) It maintains equilibrium and posture of the body by Labrynthine sensation. (3) It is concerned with somesthetic sensations such as pain, touch, temperature and pressure.

[B] **Association Areas**: These contain areas 5 and 7.

(a) **Area 5**: **Situation**: It is situated in the superior parietal lobe. **Functions**: It serves the sensory association of facial, laryngeal and cranial nerve sensations.

(b) **Area 7.** (Accessory Sensory Centre) : **Situation**: (i) It is situated below the area of 3, 2, 1. (ii) It is situated in the supra-marginal and angular gyri. **Function**: It serves the sensory association among the centres situated in the parietal lobe of the Cerebral Cortex.

III. **Temporal Lobe**: It comprises sensory area (41-42), motor area (22) and association area (20-21). This lobe concerns the different phenomenon of audition or hearing of sound.

[A] **Sensory Area 41-42** (Audio-Sensory Area) : **Situation**: It is situated in the anterior portion of superior temporal gyrus. **Function**: It helps for the recognition of hearing.

[B **Motor Area 22** (Audito-Motor Area) : **Situation**: It is situated above the area 20-21. **Functions**: It serves the movement of the voluntary organ after hearing the sound of an object from the surrounding regions.

[C] **Association Area 20-21**: (Audito-Psychic Area) : **Situation**: It is situated in the posterior part of superior temporal gyrus and on the middle and inferior temporal gyrus. **Function**: It acts as an auditory association i.e., simple hearing of sound of any person but the person is unknown.

IV. **Occipital Lobe**: It comprises sensory area (17), motor area (19) and association area (18). This lobe is entirely visual in function.

[A] **Sensory Area, 17** (True Visuo-Sensory Centre) : **Situation**: It is situated at the posterior pole and calcarine fissure of the occipital lobe. **Function**: It serves actual vision of a simple object.

[B] **Association Area, 18** (Visuo-psychic Area) : **Situation**: This area is situated on the outer surface of the occitipal lobe. **Function**: It acts as a recognition of the past memory of vision.

[C] **Motor Area, 19** (Visuo-Motor Area) : **Situation**: It is situated just above the area 18. **Function** : It serves as a movement of the voluntary organs after seeing an object.

V. **Limbic Lobe** : It is situated in the allocortex of the cerebrum and concerns about the function of taste and smell sensations.

(a) **Centre for smell** : *Situation* : It is situated in the region of uncus and hippocampal gyrus. *Function* : It acts as a sense of smell.

Centre for Taste : *Situation* : It is situated in the region of Dentate gyrus. *Function* : It helps for the sensation of taste of any types of food stuffs.

Q. 27. Describe the Structure, Connections and Functions of Thalamus.

Thalamus is collection or a group of grey matter present in the cerebral medulla perform the functions of emotion, sham-rage and receiving all sorts of crude sensations.

Development : The anterior part of the dorsal area of the diencephalon undergoes enormous thickening and form two nuclear masses which develop thalamus.

Situation : Thalamus is a collection of grey matter and is one of the muscles of deep group of cerebral nuclei, situated in the cerebral medulla. It is more or less triangular in structure, the above of which is the lateral ventricle, caudate nucleus and upper part of internal capsule ; below of which is the hypothalamus and tectum part of the midbrain ; the medial of which is the third ventricle and the lateral of which is the lower part of internal capsule and lentiform nucleus.

Thalamic Nuclei : Developmentally, the thalamus can be considered as comprising the dorsal thalamus, the ventral thalamus, the epithalamus and the metathalamus.

[A] **Dorsal Thalamus** : This contains :

(a) *Extrinsic Nuclei* : There are sometimes known as cortical relay nuclei. The extrinsic nuclei comprise :

(1) Postero-ventral Nucleus : It comprises of :
  (i) Postero-lateral ventricular (PLV) Nucleus.
  (ii) Postero-median ventricular (PMV) Nucleus.
(2) Latero-ventral Nucleus (LV)
(3) Anterior Nucleus.

(b) *Intrinsic Nuclei* : They comprise :

(1) Midline Nucleus.
(2) Intra-laminar Nucleus.
(3) Dorso-medial and Dorso-lateral Nuclei.
(4) Pulvinar Nuclei.

[B] **Ventral Thalamus** : It comprises mainly the reticular nuclear complex. It is situated between the internal capsule and the external medullary lamina.

C] **Metathalamus** : It includes as a part of thalamus. It comprises of *Medial Geniculate body* and *Lateral geniculate body*.

[D] **Epithalamus**: This comprise *Pineal body* and *Habenular complex*.

Connections of Thalamus :

I. **Afferent Thalamic Connections** : The afferent connections communicate thalamus from the surroundingstructures. The afferent thalamic connections are as follows :

(1) *Spino-Thalamic Tract* : A process starts from the posterior horn cell of the spinal cord, passes through the medulla pons, mid-brain, hypothalamus and relay to the thalamic nuclei.

(2 & 3) *Internal Arcuate fibres of Tracts of Goll and Burdach* The processes start from the nucleus gracilis and cuneatus, passes through the medulla, pons, midbrain, hypothalamus and relay to the thalamic nuclei.

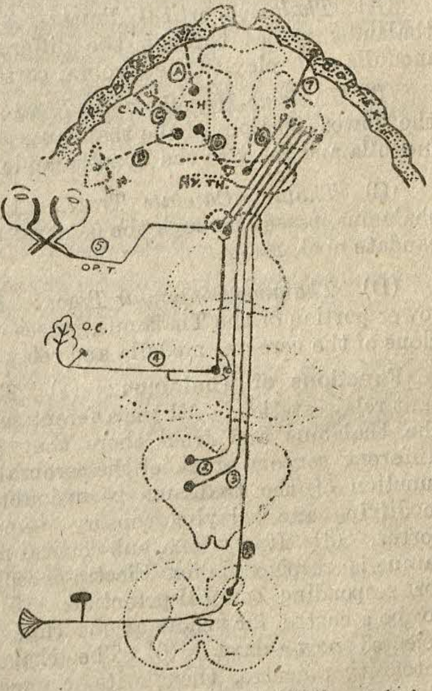


Fig. 25. Afferent (—) and Efferent (...) Connections of Thalamus.
T. H.—Thalamus, C. N.—Caudate Nucleus, L.N.—Lentiform Nucleus, Hy. TH—Hypothalamus, O. P. T.—Optic Tract, O.C.—Organ of Corti.

(4) *Audito-Thalamic Tract* : The auditory tract arises from the Organ of Corti and relay to the medial geniculate body. From there next neurone starts and relay to the thalamic nuclei.

(5) *Visuo-Thalamic Tract* : The optic tract arises from the rods and cones cells of the retina and relay to the lateral

geniculate body. From there, next neurone starts and relay to the thalamic nuclei.

(6) *Hypothalamo-Thalamic Tract* : A process starts from the hypothalamic nuclei and relay to the thalamic nuclei.

(7) *Cortico-Thalamic Tract* : A process arises from the cerebral cortex and relay to the thalamic nuclei.

II. **Efferent Connections** : The efferent connections help to transmit the received impulses from the Thalamus to the surrounding parts of the brain. The efferent connections of Thalamus are as follows :

(A) *Thalamo-Cortical Tract* : A process starts from the thalamus passes through the different regions of the cerebral medulla and relay to the cerebral cortex.

(B) *Thalamo-Hypothalamic Tract* : A process starts from the lower portion of the thalamus, passes through the cerebral medulla and relay to the hypothalamic nuclei.

(C) *Thalamo-Caudate Tract* : A process starts from the thalamus, passes through the cerebral medulla and relay to the caudate nucleus.

(D) *Thalamo-Lenticular Tract* : A process starts from the lower portion of the Thalamus, passes through the different regions of the cerebral medulla and relay to the lentiform nucleus.

Functions of Thalamus : (1) Thalamus acts as an important relay station. All the afferent sensory fibres will realy in the thalamus and from there they are redistributed to the different sensory areas of the cerebral cortex. (2) The chief function of the thalamus is undoubtedly that of receiving, modifying and relaying sensory impressions to the cerebral cortex. (3) It acts as a sub-cortical motor station. (4) Thalamus is responsible for Electro-encephalograph (E. E. G.) and for responding cortical potentials. (5) 'Pulvinar' was thought to be a centre for vision at one time but this view has been rejected now-a-days. (6) The thalamus serves as a great integrating centre, though its connections with the corpus striatum, tactile, painful, olfactory and gustatory impulses are corrected with motor reactions. (7) Emotional centre is present in the thalamus which is characterised by "Sham-rage" that is caused due to removed of cerebral cortex which we found in case of decorticated animal such as cat, dog, etc. Washing of the tail, erection of the hairs, protrusion of the claws from the paw, dilatation of the pupils, sweating, struggling and biting greatly increase rate of respiration and a rise in blood pressure are caused due to Sham rage. (8) Conjugate deviation of the head and eyes to the opposite side and movements of progression in the limbs follow electrical excitation of the ventral nucleus. (9) Coarse and heavy movement of the joints are recognised by the Thalamus.

Q. 28. Describe the Structure, Connections and Functions of Hypothalamus.

The hypothalamus is a composite mass of diencephalic structure, composed of scattered diffused nuclei, situated below the thalamus performing the function of sympathetic and parasympathetic system, body temperature regulation, sleep and control of emotion etc.

Development : The posterior part of the dorsal area of the diencephalon undergoes enormous thickening and form a group of nuclear masses which develops hypothalamus.

Situation : Hypothalamus, a composite mass of grey matter, is situated below the third ventricle and above the tectum part of the mid-brain, on the lateral side of which is the thalamus, internal capsule and lentiform nucleus.

Hypothalamic Nuclei : The hypothalamus contains many nuclear masses which may be conveniently grouped as follows :

(a) *Pre-optic Area* : It is in relations with optic chiasma. It contains Medial pre-optic nucleus and Lateral pre-optic nucleus.

(b) *Supra-optic Area* : It is also in relation with optic chiasma. It contains Supra-optic nucleus, Supra-chiasmatic nucleus, Para-ventricular nucleus and Anterior hypothalamic nucleus.

(c) *Tuberal Area* : It is situated in close relation with infundibulum and tuber cinerum. It contains Ventro-medial hypothalamic nucleus, Dorso-medial hypothalamic nucleus, Arcuate nucleus, Lateral hypothalamic nucleus and Posterior hypothalamic nuclei.

(d) *Mammillary Area* : It is in close relation to the wall of the third ventricle and mammillary body. It contains Medial and Lateral mammillary nuclei pre—and supra-mammillary nuclei and Intercalatus nucleus.

Connections of Hypothalamus : The connections are afferent and efferent in type.

I. **Afferent Hypothalamic Connections** : The afferent connections receives impulses from the neighbouring structures. The afferent connections of hypothalamus are :

(1) *Cortico-Hypothalamic Tract* : A process arises from the cerebral cortex, passes though the different regions of the cerebral medulla and relay to the hypothalamic nuclei.

(2) *Hippocampo-Hypothalamic Tract* : A process starts from the hippocampal region of the cerebral allocortex, passes through the different regions of the cerebral medulla and relay to the mammillary body of the hypothalamus.

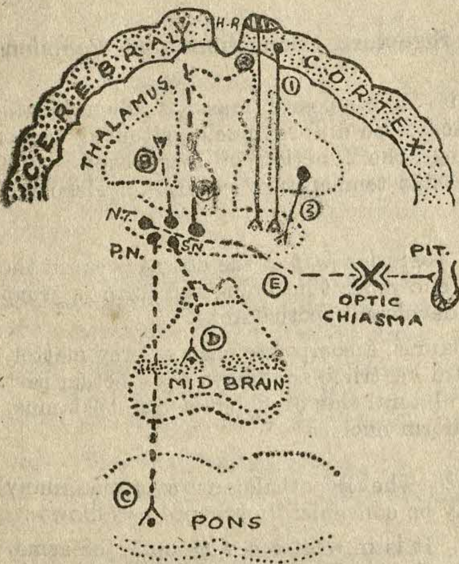


Fig. 26. Afferent (—) and Efferent (. .) Connections of Hypothalamus.
H. R.—Hippocampal region, N. T.—Nucleus Tuberalis, S. N.—Supra-optic Nucleus, P. N.—Paraventicular Nucleus, PIT.—Pituitary body.

(3) *Thalamo-Hypothalamic Tract* : The process starts from the thalamus, passes through the different portions of the cerebral medulla and relays to the hypothalamus.

II. **Efferent Connections** : The efferent connections relay to the different neighbouring structures of the brain. The efferent connections of the hypothalamus are :

(A) *Hypothalamo-Cortical Tract* : A process starts from the hypothalamus, passes through the different regions of the cerebral medulla and relay to the cerebral cortex.

(B) *Hypothalamo-Thalamic Tract* : A process starts from the hypothalamus, passes through the different regions of the cerebral medulla and relay to the thalamus.

(C) *Paraventriculo-bulbar Tract* : A process starts from the Paraventricular nucleus, passes through the mid-brain and relay to the pons and medullary region of the brain stem.

(D) *Supra-optico-bulbar Tract* : A process starts from the Supra-optic nucleus, passes through tectum, tegmentum of mid-brain and relay there.

(E) *Tubero-Hypophyseal Tract* : A process arises from the Nucleus tuberalis, passes through hypothalamic region, optic chiasma and relay to the posterior lobe of Hypophysis cerebri or Pituitary body.

Functions of Hypothalamus: A brief summary of the experimental evidences relating to hypothalamic functions will be given below :

(1) **Liberation of Hormnes**: Hypothalamus controls the secretion of different hormones from the posterior pituitary gland specially the hormone A.D.H. from this gland.

(2) **Control of the secretion Hormones**: Hypothalamus thorough the hypothalamic hormone, which passes through hypothalamo-hypophyseal portal system of veins and controls the secretion of the hormones from the anterior pituitary gland.

(3) **Regulation of Sympathetic Nervous System**: The posterior group of hypothalamic nuclei controls the sympathetic nervous system because the sympathetic nervous centre is situated in the hypothalamus.

(4) **Regulation of Parasympathetic Nervous System**: The middle group of hypothalamic nuclei controls parasympathetic nervous system because parasympathetic nervous centre is situated in the hypothalamus.

(5) **Regulation of Normal Body Temperature**: Hypothalamus regulates normal body temperature because temperature regulating centre is situated in the hypothalamus. The posterior hypothalamic nucleus through the sympathetic system will control the body temperature in cold climate.

(6) **Concerned with Sleep**: Hypothalamus controls sleep because sleeping centre is situated in the hypothalamus. The mammillary body of posterior group of hypothalamic nuclei is related to sleep.

(7) **Centre for Emotion**: Hypothalamus controls the action of emotion because emotional centre is situated in the hypothalamus.

(8) **Regulation of Water Balance**: Hypothalamus controls water balance because water balance centre is situated in the hypothalamus.

(9) **Regulation of Carbohydrate Metabolism**: Hypothalamus regulates carbohydrate metabolism. Stimulation of the lateral nuclei causes temporary hyperglycaemia and glycosuria. Damage to the paraventricular nuclei results in enduring hypoglycaemia.

Q. 29. Describe the Structure, Connections and Functions of Corpus Striatum.

The corpus striatum is a mass of grey matter, consists of smaller anterior caudate nucleus and largor posterior lentiform nucleus. It is situated in the cerebral medulla and concerns about visual, tactile and other sorts of impressions.

Anatomy : The corpus striatum is divided incompletely by the anterior limb of the internal capsule into smaller anterior caudate nucleus and larger posterior lentiform nucleus. The caudate nucleus comprises body and tail. The lentiform nucleus consists of larger putamen and small globus pallidus.

Histology : The *Caudate nucleus* and the *Putamen* of the Lentiform nucleus are composed of small stellate cells. The *globus pallidus* possesses large pyramidal and multipolar cells resembling Betz cells and anterior horn cells respectively and rich in medullated fibres.

Development : The corpus striatum is a mass of grey matter which develops in the ventral part of the primitive hemisphere in the area immediately adjoining the interventricular foramen.

Connections of Corpus Striatum :

I. **Internuncial Fibres** : The fibres arising and ending within the mass of corpus striatum.

(1) From Caudate nucleus to Putamen.

(2) From Putamen to Globus Pallidus.

(3) From Lateral globus pallidus to Medial globus Pallidus.

II. **Afferent Connections** : (Strio-Fugal fibres) : All fibres arising from globus pallidus and ending elsewhere :

(a) **Strio-thalamic** : From globus pallidus to the lateral nucleus of thalamus.

(b) **Strio-Subthalamic** : From globus pallidus to :

(1) Strio-rubral—to Red nucleus.

(2) Strio-nigral—to Substantia nigra.

(3) Body of Luys.

(4) Superior colliculus. (5) Vestibular Nucleus.

(6) Formatio Reticularis. (7) Olivary Nucleus.

(8) Hypothalamus. (9) Strio-bulbar—to oculo-motor and other motor cranial nuclei.

III. **Afferent Counections** (Strio-petal Connections) :

Fibres arising elsewhere but ending in the corpus striatum. (1) Thalamo-striate : Thalams to Caudate nucleus and globus pallidus. (2) From body of Luys to Caudate Nucleus. (3) From Body of Luys to globus pallidus. (4) From Red nucleus to globus pallidus. (5) Cortico-striate—From Area 6 of Cerebral Cortex to caudate nucleus and Putamen.

IV. **Commissural Fibres** : Fibres arising from globus pallidus of one side to that of opposite side.

Functions of Corpus Striatum :

(1) It is a rudimentary or primitive motor cortex concerned with all types of movements connected with the manifestations of life.

(2) Corpus striatum is concerned with the generalised purposeful movement for the execution of daily activities.

(3) It is concerned with the group movement, associated with motion and automatic associated acts.

(4) It inhibits the resting cortical potential. Stimulation of the corpus striatum leads into either inhibition or excitation of movements according to the site of stimulus.

(5) Corpus striatum controls tone, posture and equilibrium and adjusts the postural mechanism which makes the volitional movements smooth, accurate and purposeful.

Q. 30. Describe the different parts, connections and functions of Internal Capsule.

The Internal capsule is the projection fibres made up of a strip of white fibres of the neopallium. It is a "V" shaped band of white fibres connecting the cerebral cortex of neopallium to different levels of brain stem and spinal cord.

Situation : The Internal capsule is situated in between the lentiform nucleus on the lateral side and the caudate nucleus and the thalamus on the medial side.

Different Parts : The Internal capsule is divided into an anterior limb, a posterior limb and a genu. The anterior limb is interposed between the lentiform nucleus on the lateral side and head of the caudate nucleus on the medial side. The posterior limb has the thalamus on its medial side and a lentiform nucleus on its inner side. The different parts of the internal capsule are :

(a) *Anterior Limb* : It forms Lentioulo-caudate part.

(b) *Posterior Limb* : It constitutes :

(1) Lenticulo-thalamic part.
(2) Retro-lentiform part.
(3) Sub-lentiform part.

(c) *Genu* : It is a junction of anterior and posterior limbs.

Connections : The connections of Internal capsule are as follows :

I. **Anterior Limb** :

(1) The lateral and the anterior nuclei of the thalamus to the frontal lobe. (2) From the frontal lobe to the lateral

nucleus of the thalamus. (3) From the cerebral cortex to the corpus striatum. (4) From the lentiform nucleus to the caudate nucleus. (5) From the frontal lobe to the nuclei pontis. (6) The efferent projection fibres for the head and eyes.

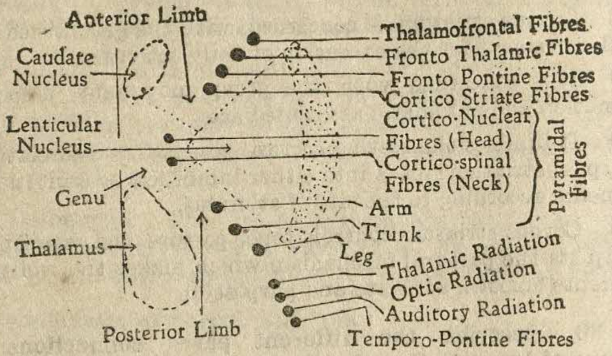


Fig. 27. Schematic Representation of the Internal Capsule showing the arrangement of sensory and motor fibres within it.

II. **Genu :** It is composed of cortico-bulbar fibres for the mouth and tongue.

III. **Posterior Limb** : It is composed of the following fibres :

(1) The anterior 2/3rd being composed of the cerebral spinal nerve fibres.

(2) The posterior 1/3rd comprising of :

(i) The sensory fibres from the thalamus to the somesthetic area of the cerebral cortex.

(ii) The optic radiation fibre from the lateral geniculate body to the calcarine area.

(iii) The auditory or acoustic radiation fibre from the medial geniculate body to the superior convolution.

(iv) The temporo-pontine and cortico-potine fibres.

(v) Cortico-rubral tract from the frontal lobe to the red nucleus.

Functions of Internal Capsule :

(1) It prevents muscular weakness, movements concerning limbs, trunk and face of the opposite side.

(2) It maintains the movement of jaw, tongue and soft palate of the opposite side.

(3) It prevents the phenomenon of hypertonicity of the muscles.

(4) The tendon jerks at knee, ankle and elbow are exaggerated on the hemiplegic side and there may be ankle clonus. The planter response is extensor in type, the abdominal and cremasteric reflexes are reduced and abolished.

Q. 31. What is Sleep ? What are the physiological changes during sleep ? Describe the theories concerning sleep in man.

Sleep is a temporary physiological suspension of consciousness in which there is a temporary inhibition of motor and sensory activities of the cells of the cerebral cortex. The animals and man show one sleep period in 24 hours. The night being inactive and is used for sleep, but in night workers, day-sleeping is the habit. The duration of sleep varies inversely with age. For the new-born infants, 18 to 20 hours a day ; young children, 12 to 14 hours a day ; adults, 7 to 9 hours a day and the old aged people sleeps about 5 hours a day. The intensity or the depth of sleep varies during the sleep. It reaches its maximum 2 to 3 hours after the onset of sleep. In case of children, there are two maximum periods —one between first and second hours and the other between eighth and ninth hours.

Physiological changes during Sleep : There are a number of physiological changes that take place during sleep, are given below :

(1) **Circulatory System** : (i) The force and frequency of the heart are diminished. (ii) The pulse rate is slowly diminished. (iii) The blood pressure falls. (iv) The cardiac output and vasomotor tone are diminished.

(2) **Respiratory System** : (i) The respiration becomes slower and deeper. (ii) Sometimes respiration shows cheyne-stokes type of breathing. (iii) The tidal volume and pulmonary ventilation are lowered.

(3) **Excretory System** : (i) Urine volume less. (ii) The reaction of the urine is variable. (iii) The specific gravity and amount of phosphates are raised.

(4) **Secretion** : (i) The glandular secretions such as saliva, tears and adrenaline are diminished. (ii) The sweat secretion is increased.

(5) **Special Sense (Eye)** : (i) The eye balls roll up and out due to flaccid external ocular muscles. (ii) The eyelids come closer, specially due to the drooping of the upper eyelids. (ii) The pupils are contracted but light reflex is retained during sleep.

(6) **Nervous System** : (i) In Electroencephalogram, an appearance of delta waves. (ii) The deep reflexes are reduced. (iii) The Babiniski's sign is positive. (iv) The superficial reflexes are unchanged. (v) The vasomotor reflexes are more brisk.

(7) **Metabolism** : (i) The metabolic oxidation is reduced by 10% to 15%. (ii) The oxygen consumption is diminished.

Theories Concerning Sleep : There are several theories to explain the phenomenon of sleep but none of them come into final conclusion.

(1) **Howell's Theory** : Sleep is due to cerebral ischeamia which is due to loss of tone of vasomotor centre. It gets fatigued and there is loss of tone causing peripheral vasodilatation, fall of blood pressure and diminished supply of oxygen to the brain.

(2) **Pavlov's Theory** : Sleep is due to the process of internal conditioned inhibition which inhibits the functions of cerebral cortex. It is due to the spread of an internal inhibitory process and is considered the concomitant sleep as a symptom of the cortical inhibition.

(3) **Biochemical Theory** :

(a) **Toxin Theory** : According to *Dikshit*, sleep is caused due to the accumulation of acetycholine in the cerebral cortex. There is no evidence in support of this theory.

(b) **Lactic acid Theory** : Sleep is caused due to the accumulation of lactic acid in the tissue during fatigue. Lactic acid depresses the activities of the cerebral cortex. The muscle sense is diminished and no impulse reaches to the brain.

(4) **Kleitman's Theory** : *Kleitman* observed that the reticular formation plays and important role in the production of sleep. The afferent impulse arises from the spinal cord, carried through the peripheral nerves and relay to the reticular formation. The reticular activity causes wakefulness but during sleep, the reticular formation remains inactive. It is the more acceptable theory than others.

Q. 32. Describe the Structure, Connections and Functions of Cerebellum.

The cerebellum, a small brain, is a vast organ of the motor system, situated at the ventral aspect of the brain stem and connected by three pairs of peduncles with it. It guides the cerebral cortex to carry out the voluntary movements and plays an important role in the regulation of posture.

Situation : The cerebellum which constitutes the largest part of the hind brain lies in the posterior fossae of the cranium under the occipital lobes and behind the brain stem.

The two cerebellar hemispheres are connected to each other by a narrow central bridge known as vermis.

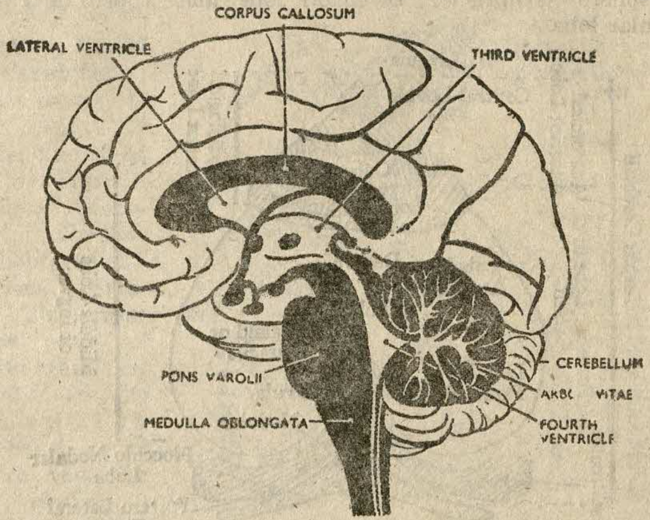


Fig. 28. Diagrammatic representation of the median sagittal section of the brain showing the position of Cerebellum.

Development : The brain during development forms three enlargements and are named from before backwards, the Procencephalon, Mesencephalon and Rhombencephalon. The anterior part of Rhombencephalon is known as Metencephalon. The metencephalon during its course of development forms roof plate, floor plate, basal lamina and alar lamina. Cerebellum is developed from alar lamina.

Anatomy or Morphology :

I. **Broadly** : The cerebellum consists of : (a) *Vermis or* a central part which consists of Superior vermis on the upper aspect and inferior vermis on the inferior aspect. (b) *Two lateral cerebellar hemispheres* situated on the two lateral sides.

II. **Anatomically** : The cerebellum is divided anatomically into following parts :

(a) **Anterior Lobe** : It consists of vermis and cerebellar hemisphere. (1) The vermis consists of Lingula, Lobus centralis, Culamen, Clivus. (2) The cerebellar hemisphere consists of Anterior medullary vellum, Alae lobus centralis, Anterior part of quadrate and posterior part of the quadrate lobe.

(b) **Posterior Lobe** : (1) *Anterior Part* : It consists of vermis comprising Lobules simplex and Tuber vermis and

Cerebellar hemisphere comprising Superior semilunar lobe and Inferior semilunar lobe. (2) *Posterior Part* : It consists of vermis comprising Pyramid and Uvula and Cerebellar hemisphere comprising Biventral lobe and Tonsil of Parafloccular lobe.

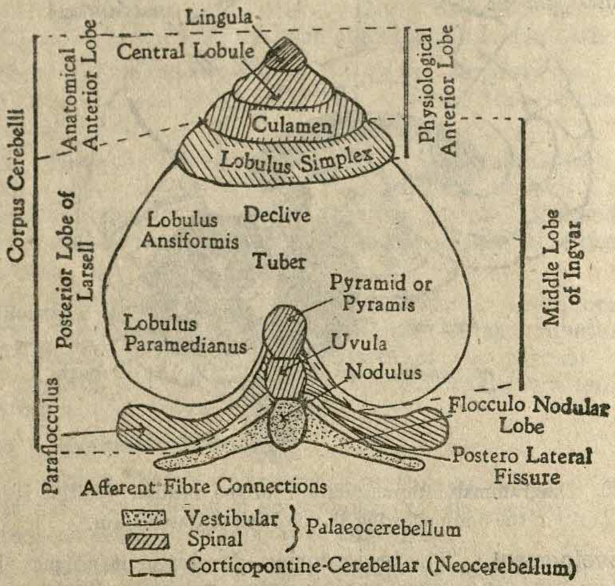


Fig. 29. Schematic representation of Main Divisions of the Cerebellum.

Histology of Cerebellum : Histologically, cerebellum is divided into outer cerebellar cortex and the inner cerebellar medulla.

I. **Cerebellar Cortex** : The grey matter of the cerebellar cortex shows three layers : The outermost is the *molecular layer*, the middle is the *Purkinje cell layer* and innermost is the *granular layer*. Beneath this, is the white matter.

(a) **Outer Molecular Layer** : It is the outermost layer and is composed of : (1) Branching dendrons of the Purkinje cells. (2) Branches of the axons of the granule cells of the internal granular layer. (3) Climbing fibres. (4) Basket cells. (5) The small stellate cells.

(b) **Middle Purkinje Cell Layer** : This layer is composed of only the Purkinje cells which are large flask shaped cells with freely branched dendrons.

(c) **Inner Granular Layer** : It is the deepest layer and consists of : (1) Granule cells which are very small nerve cells. (2) A few cells of Golgi Type II. (3) Neuroglea Cells.

II. **Cerebellar Medulla**: It consists of white fibres and a patch of grey matter that contains deep cerebellar nuclei.

(a) **Deep Nuclei of Cerebellum**: These consist of four pairs of nuclei known as Nucleus Fastigii, Nucleus Globosus, Nucleus Emboliformis and Nucleus Dentatus. The former three pairs of nuclei are mostly situated in the vermis which overhangs the fourth ventricle and phylogenetically older than the Nucleus Dentatus.

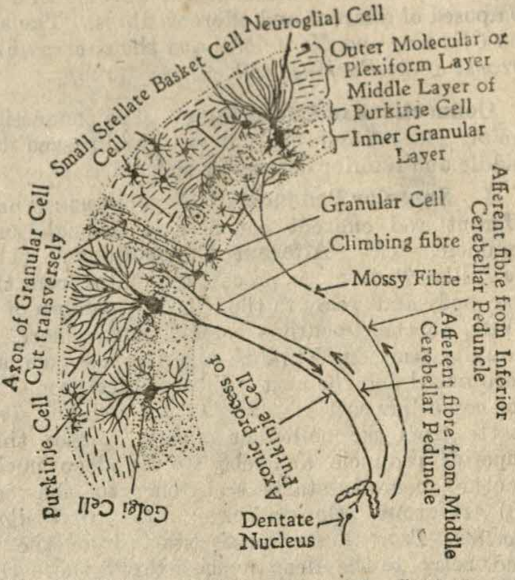

Neuroglial Cell
Basket Cell
Small Stellate Cell
Outer Molecular or Plexiform Layer
Middle Layer of Purkinje Cell
Inner Granular Layer
Granular Cell
Climbing fibre
Mossy Fibre
Afferent fibre from Inferior Cerebellar Peduncle
Afferent fibre from Middle Cerebellar Peduncle
Axon of Granular Cell Cut transversely
Axonic process of Purkinje Cell
Purkinje Cell
Golgi Cell
Dentate Nucleus

Fig. 30. Histological Structures of the Cerebellum showing the different cells and fibres present in the Cortex and Medulla.

(b) **White Fibres of Cerebellum**: The white matter of

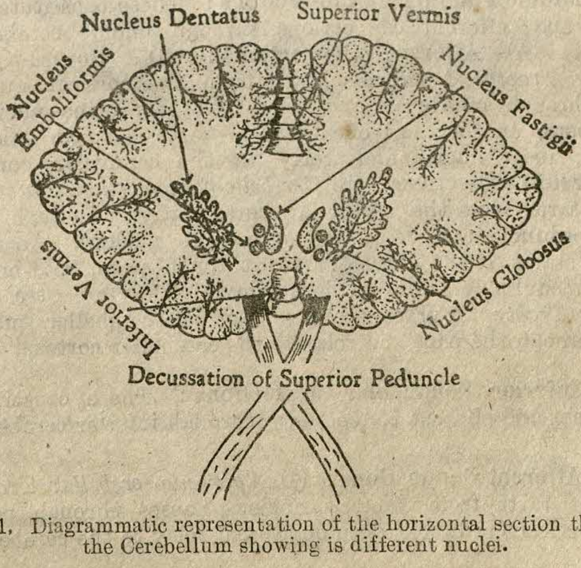


Fig. 31. Diagrammatic representation of the horizontal section through the Cerebellum showing is different nuclei.

the cerebellum is composed of two types of nerve fibres such as projection fibre and commissural fibres. The projection fibres composed of afferent and efferent fibres. The afferent fibres are the *Climbing* and *Moss fibres* and the efferent fibre is the *axonic process of the Purkinje cell.*

Connections of Cerebellum : The connections of cerebellum are of afferent and efferent type and passed through superior, middle and inferior cerebellar peduncles.

I. **Superior Peduncular Connections :** These constitute the afferent and efferent connections through superior cerebellar peduncle. (A) **Afferent Connections** : (1) *Ventro-Spino-Cerebellar Tract* : A process originates from the lower half of the body and relay to the Clarke's column of the spinal cord. Then another neurone starts from there, passes through medulla, pons, mid-brain, superior peduncle and relay to the deep nuclei and the next neurone starts from there and relay to the cerebellar cortex. (2) *Tecto-Cerebellar Tract* : A process starts from the collicular nucleus, passes through mid-brain, superior peduncle and relay to the deep nuclei. From there, another neurone starts and relay to the cerebellar cortex. (B) **Efferent Connections** : (a) *Cerebello Rubro-Thalamo-Cortical Tract* : A process starts from the cerebellar nuclei and relay to the deep nuclei. From there the next neurone starts, passes through the superior peduncle and relay to the red nucleus. From there, the next neurone arises from there and relay to cerebral cortex.

II. **Middle Peduncular Connections** : These constitute the afferent and efferent connections through middle cerebellar peduncle. (A) **Afferent Connections** : (3) *Cortico-ponto-cerebellar Tract* : A process starts from the cortical nuclei, passes through mid-brain and relay to the pontine nucleus. From there, another neurone starts, passes through middle peduncle, deep nuclei and relay to the cerebellar cortex. (B) **Efferent Connections** : (b) *Cerebello-ponto-cortical Tract* : A process starts from the cerebellar cortex, passes through the middle peduncle and relay to the pontine nucleus. Another neurone starts from there, passes through pons, mid-brain, cerebral medulla and relay to the cortical nuclei. (c) *Cerebello-cerebellar Tract* : A process starts from the cerebellar nuclei, passes through the pons and relay to the cerebellar cortex.

III. **Inferior Peduncular Connections** : These constitute the afferent and efferent connections through inferior cerebellar peduncle.

(A) **Afferent Connections** : (4) *Vestibulo-cerebellar Tract* : A process starts from Dieter's nucleus, passes through pons, medulla, inferior peduncle, deep nuclei and relay to the cerebellar

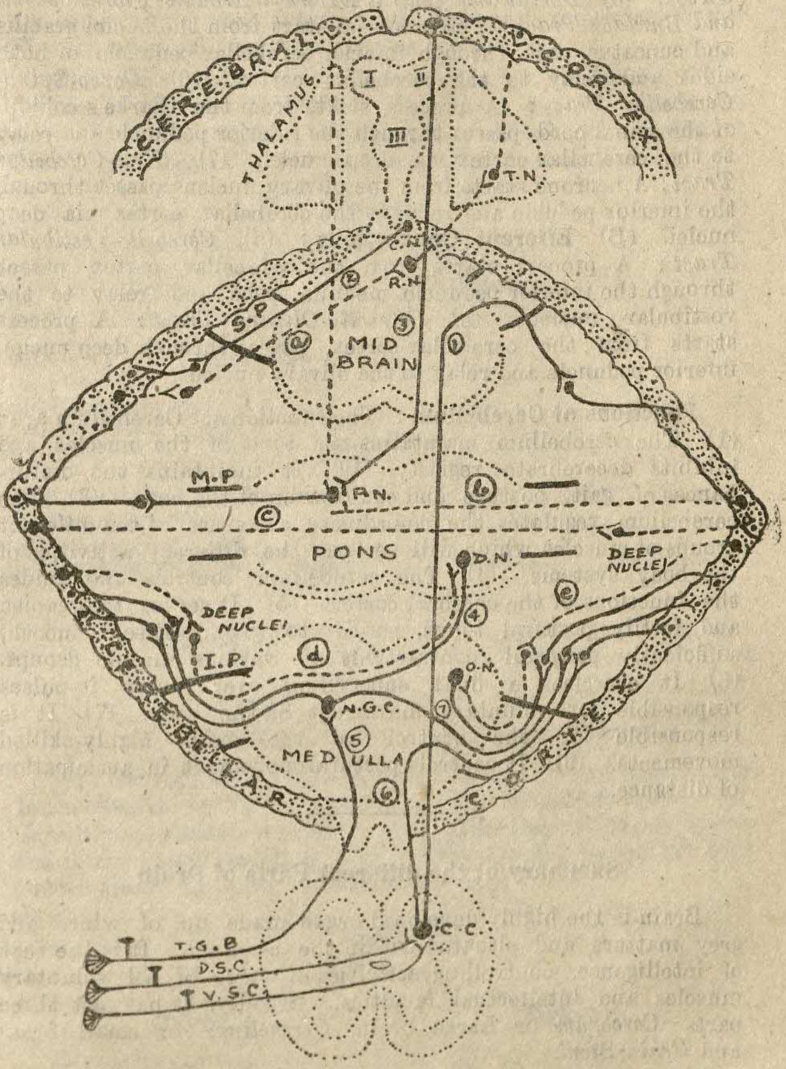


Fig. 32. Afferent [—] and Efferent [...] Connections of Cerebellum.

T. N—Thalamic Nuclei, I, II, III—Ventricles, C.N—Collicular Nucleus, R. N—Red Nucleus, S. P—Superior Peduncle, M. P—Middle Peduncle, I. P—Inferior Peduncle, P. N—Pontine Nucleus, D. N—Dieter's Nucleus, O. N—Olivary Nucleus, N. G. C—Nucleus Gracilis and Cuneatus, C. C—Clarke's Column, T. G. B---Tracts of Goll and Burdach, D. S. C---Dorso-Spino-Cerebellar Tract, V. S. C---Ventro-Spino Cerebeller Tract.

cortex. (5) *Dorsal and Ventral External Arcuate Fibres of Goll and Burdach Tract* : The processes start from the nuclei gracilis and cuneatus, pass through inferior cerebellar peduncle of both sides and relay to the cerebellar cortex. (6) *Dorso-Spino-Cerebellar Tract* : A process starts from the Clarke's column of the spinal cord, passes through the inferior peduncle and relay to the cerebellar cortex via deep nuclei. (7) *Olivo-Cerebellar Tract* : A neurone starts from the olivary nucleus passes through the inferior peducle and relay to the cerebellar cortex via deep nuclei. (B) **Efferent Connections :** (d) *Cerebello-Vestibular Tract* : A process starts from the cerebellar cortex, passes through the inferior peduncle, medulla, pons and relay to the vestibular nucleus. (e) *Cerebello-Olivary Tract* : A process starts from the cerebellar cortex, passes through deep nuclei, inferior peduncle and relay to the olivary nucleus.

Functions of Cerebellum : The functions of Cerebellum are : (1) The cerebellum maintatins the tone of the muscles and inhibits decerebrate regidity. (2) It maintains the disturbances of gait, posture and equilibrium of the body. (3) The cerebellum regulates the co-ordinate activities of the different groups of muscles which will perform the different activities of the body systems. (4) The cerebellum controls and guides the functions of the cerebral cortex. (5) It serves to organise and fortify postural tonus, so as to give precise, smooth, sufficiently powerful contractions of various muscle groups. (6) It exercises a final supervition over motor impulses responsible for voluntary movement of the body. (7) It is responsible for the control of the most highly-skilled movements. (9) It controls postural movement in anticipation of distance.

Summary of the different Parts of Brain :

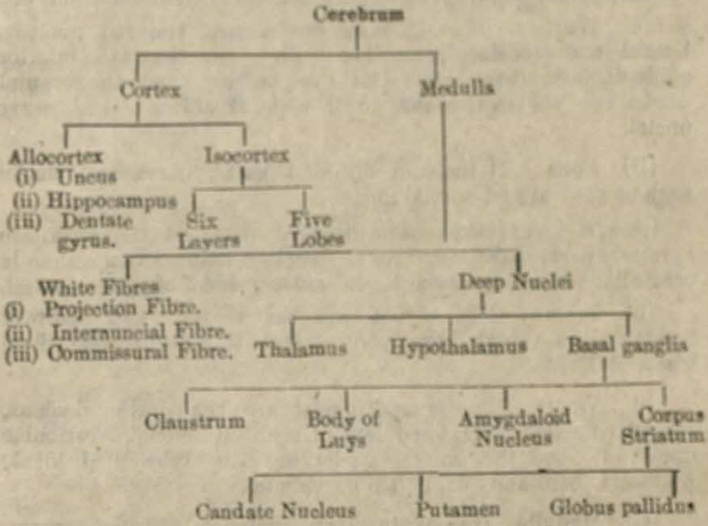
Brain is the highly developed organ made up of white and grey matters and situated within the cranium. It is the seat of intelligence, controlling activities of sorts of all voluntary muscles and intellectual faculties. Broadly, it has got three parts—*Cerebrum* or Large brain, *Cerebellum* or small brain and *Brain-Stem*.

I. **Cerebrum** : It has got outer cortex and inner medulla.

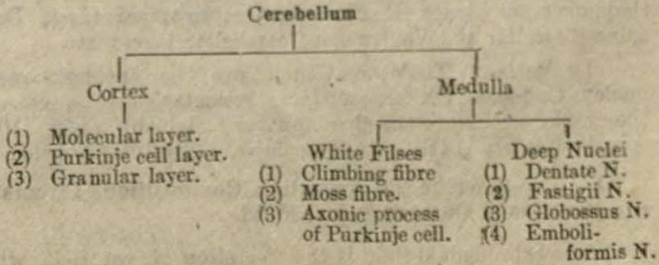
(a) **Cortex**: It consists of palaeo-allocortex and neo-Isocortex. The allocortex consists of uncus, hippocampus and dentate gyrus. The isocortex consists of six fundamental layers and five lobes nemely frontal, parietal, occipital, temporal and limbic lobes.

(b) **Medulla** : It consists of white fibres and a patch of grey matter known as deep nuclei of cerebrum. The white fibres are commissural fibre, internuncial fibre and projection fibres. The commissural fibre forms *corpus callosum*.

The deep nuclei of cerebrum comprise of *Thalamus*, *Hypothalamus* and *Basal ganglia*. The basal ganglia consists of corpus striatum (caudate nucleus, putamen and globus pallidus), Claustrum, Body of Luys and Amygdaloid nucleus.



II. Cerebellum : It is the small brain situated behind the brain-stem connected by superior, middle and inferior peduncles. Cerebellum consists of outer cortex consisting of three layers and inner medulla consists of white fibres and a patch of grey matter known as deep nuclei of cerebellum.



III. Brain-Stem : It includes mid-brain, pons varoli and medulla oblongata.

[A] **Mid-Brain** : It includes different parts, fibres and nuclei such as general and cranial nuclei.

(a) *Different Parts* : The parts of mid-brain are tectum, tegmentum, substantia nigra, superior cerebellar peduncle, or crus or pes, Aqueduct of sylvius, etc.

(b) *Fibres* : The fibres are the fronto-pontine fibre, cortico-nuclear fibre, rubro-spinal tract, tecto-spinal tract, reticulo-spinal tract, spino-tectal tract, spino-thalamic tract, etc.

(c) *Nuclei* : The general nuclei are the red nucleus, lateral and medial geniculate bodies, superior and inferior collicular structures, pre-tectal nucleus, etc. and the cranial nuclei are the oculomotor (3rd) and trochlear (4th.) nerve nuclei.

[B] **Pons** : It includes different parts, fibres and nuclei such as general and cranial nuclei.

(a) *Different parts* : The different parts of the pons are anterior part, posterior part, corpus trapezodium, middle cerebellar peduncle, medial leminiscus, aqueduct of pons, etc.

(b) *Fibres* : The fibres are the visual tract, auditory tract, reticulo-spinal fibre, ponto-spinal tract, vestibulo-spinal tract, etc.

(c) *Nuclei* : The general nuclei are the pontine nucleus, reticular nucleus, dorsal and ventral cochlear nuclei, vestibular nuclei, etc. and the cranial nuclei are the Trigeminal (5th), Abducent (6th) and facial (7th) nerve nuclei.

[C] **Medulla Oblongata** : It includes different parts, fibres and nuclei such as general and cranial nuclei.

(a) *Different parts* : The different parts of medulla oblongata are pyramid, inferior cerebullar peduncle, aqueduct of medulla, posterior longitudinal bunndle, etc.

(b) *Fibres* : The fibres are the tract of Gowers, spino-thalamic tract, tract of Fleschsig, rubro-spinal tract, Dorso-spino-cerecellar and Ventro-spino-cerebellar tracts, etc.

(c) *Nuclei* : The general nuclei are the nucleus Gracilis, nucleus Cuneatus, Olivary nucleus, reticular nucleus, etc. and the cranial nuclei are the glosso-pharyngeal (9th), vagus (10th), spinal accessory (11th) and Hypoglossal (12th) nerve nuclei.

Q. 33. Discribe the Formation, Composition, Circulation and Functins of Cerebro-Spinal Fluid.

The cerebro-spinal fluid is the secretion of ventricle which lies in the space formed by the cavity from cerebrum upto the spinal cord. It is a modified tissue fluid present in sub-arachnoid space of brain and central canal of spinal cord and in different ventricles. This fiuid bathes the central nervous system. It is formed in the lateral ventricle of brain from choroid plexus.

Anatomical Considerations : The dural and arachnoid membranes form the meningeal coveringof the sac which contains the cerebro-spinal fluid (C.S.F.). The circulating path of C.S.F. is narrow but it is wider in different places forms thereby the cisterna. The principal dilatations are the *cisterna magna* below the cerebellum and above the medulla, the *cisterna pontis* on the ventral aspect of the pons and the *cisterna basilis*, which contains the circles of Willis. The sub-arachnoid space is lined with flattened epithelial cells and at intervals, particularly in association with arachnoid villi and clumps of phagocytic cells called meningocytes.

Formation of Cerebro-Spinal Fluid :

I. **Site of Formation :** The vascular choroid plexus which project into all the choroid plexus of the lateral ventricles. They are vascular fringe-like processesof piamater or tuft of capillaries derived from pial blood vessels, covered by a layer of cells continuous with the ciliated epthelium lining the ventricles.

II. **Rate of Formation** : We have seen with lumbar puncture that the rate of C. S. F. in adults about 20 ml. per hour or 500 ml. per day.

III. **Mechanism of Formation** : The C. S. F. is formed partly by the process of mechanical filtration and partly by the secretory activity of the cubical cells that cover the choroid plexus.

Composition of Cerebro-Spinal Fluid :

I. **Physical Properties** :

(1) **Nature** : It is a clear, colourless, transparent fluid, does not coagulate on standing.

(2) **Total Quantity :** In man, it is about 150 ml.

(3) **Hydrogen-ion-concentration** (PH) : It becomes 7·3 to 7·4.

(4) **Reaction** : It is alkaline in rection,

(5) **Specific Gravity** : It becomes 1004 to 1006.

(6) **Pressure** : The pressure inside the cranial cavity is about 100 mm. of H_2O in recumbent subjects. The variation of pressure occurs on standing, coughing, sneezing, crying etc.

II. **Chemical Composition** : The chemical composition of C. S. F. is rather like that of lymph. In disease, changes in the chemical composition and cells of the C. S. F. may take place. The water contains 92·13% and the total solids become 0·87%.

(A) Non-Celluar Elements :

(a) *Organic Constituents* : These contain Total Protein—16 to 38 mgm%, Amino-Acids—1·5 to3·0 mgm%, Creatinine—0·65 to 2·2 mgm%, Uric acids—0·5 to 2·8 mgm%, Urea—10 to 30 mgm%, Sugar—45 to 80 mgm%, Lactic acid—8 to 27 mgm%, etc.

(b) *Inorganic Constituents* : These contain Chloride—720 to 750 mgm%, Inorganic phosphate—1·25 to 2·0 mgm%, Bicarbonates—40 to 60 mgm%, Sodium—325 mgm%, Potassium—12 to 17 mgm%, Magnesium—3 to 3·6 mgm%, Calcium—4 to 7 mgm% etc.

(B) **Cellular Elements :** These comprise of Lymphocytes—1 to 5 per cu. mm. of C.S.F. and Polymophonuclear Leucocytes.

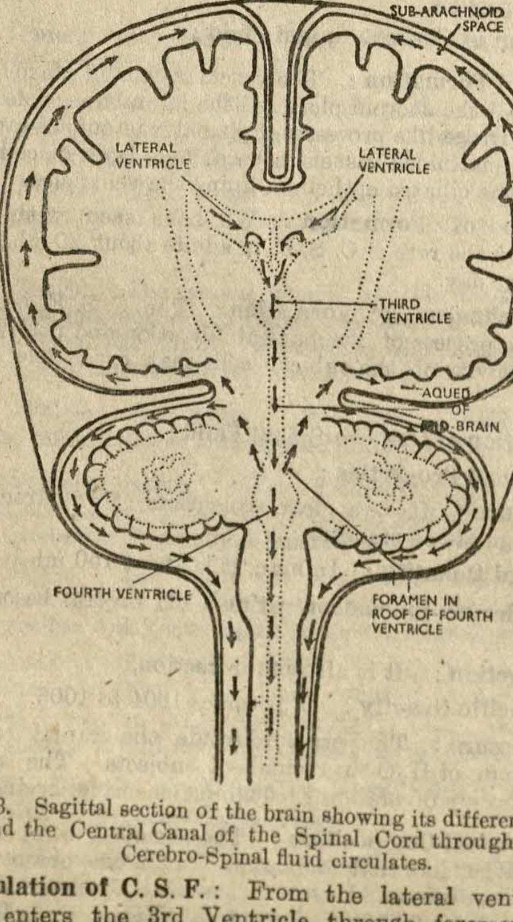


Fig. 33. Sagittal section of the brain showing its different Ventricles and the Central Canal of the Spinal Cord through which the Cerebro-Spinal fluid circulates.

Circulation of C. S. F. : From the lateral ventricles, the C. S. F. enters the 3rd Ventricle through foremen of Monro and from 3rd Ventricle to 4th Ventricle through the aqueduct of Sylvius. From the 4th Ventricle C. S. F. will enter into the sub-arachnoid space of the brain and spinal cord through the leteral openings, known as foramen of Luschka and one inferior opening known as Foremen of Magendie. The central opening of the 4th ventricle is continuous with central canal of the spinal cord. From the sub-arachnoid spaces of the brain, C. S. F. will go to the different venous sinuses of the brain through the sub-arachnoid villi.

Functions of C. S. F. (1) It acts as a *fluid buffer.* A watery layer surrounds the brain and spinal cord that protects these structures from external injury. (2) C. S. F. regulates the *volume of cranial contents* when cranial contents increase, there is greater absorption of C. S. F. into venous sinuses and to the volume of cranial content is maintained constant. (3) It is the medium through which the nutritive materials of the brain and spinal cord will circulate and thereby performing *excretory function.* (4) The lymphocytes present in C. S. F. will protect the brain matter from bacterial infection and serves *protective function.* (5) It acts as the *Lymph of the brain*, a middle man or intermediary medium for bringing in-oxygen and nutrition and for taking out catabolic products such as carbon dioxide. (6) It acts as an *intracerebral gill*, concerned with respiration. (3) C. S. F. carries pituitary hormones which are absorbed by the blood vessels that serves as a *hormonal function.* (8) It *maintains the Intra-cranial pressure.*

Q. 34. Give a short account of the Autonomic Nervous System. Or, "The Sympathetic provides for the work of to-day and the Parasympathetic for the work of to-morrow" —Discuss the Statement.

The autonomic nervous system is divided into two divisions —*sympathetic* and *parasympathetic* which are involuntary in action and regulates vital functions. Whenever these two system of nerves are distributed to any tissue or organ, they are antagonist in action. They distribute their impulses through ganglionic cells. The sympathetic ganglia are nearer to the central nervous system and away from the tissues they innervate whereas parasympathetic ganglia are away from the central nervous system but closer to the tissues they supply.

I. Parasympathetic System : This system is a part of autonomic nervous system which is anabolic in function.

Origin : It consists of cranio-sacral nerves. The cranial nerves are 3rd, 7th, 9th and 10th. The fibres arise from the lateral horn cells of 2nd, 3rd and 4th sacral segments, are also included in parasympathetic nervous system.

Course with Distribution : Though parasympathetic system originates from cranial nuclei and sacral nuclei, so they are of cranial and sacral outflows.

[A] **Cranial Outflow** : (a) *Third Cranial Nerve* : The cell of origin from the cranial part of Edinger Westphal nucleus of the 3rd nerve nucleus which is situated in the mid-brain of the brain-stem. The pre-ganglionic fibres end in the ciliary ganglia. The post-ganglionic fibres as short ciliary nerve supply the following structures : (1) Ciliary muscles of the eye. (2) Constrictor pupillae of iris.

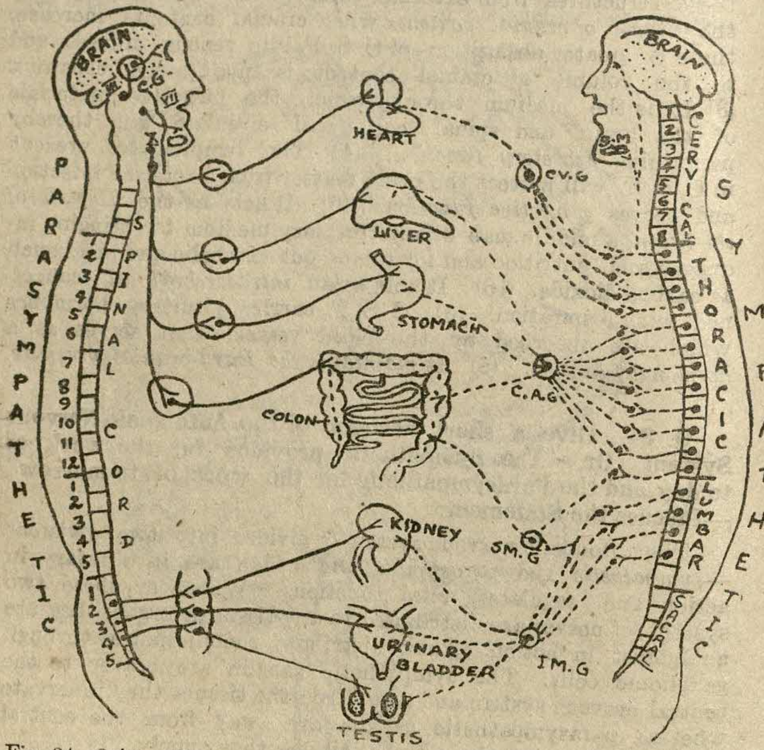


Fig. 34. Origin, Course and Distributions of Autonomic Nervous System. C.G—Ciliary Ganglia, III, VII, X—Cranial Nerves, S. M—Sub-mandibular Ganglia, CV. G—Cervical Ganglia, C.A G—Coeliac and Abdominal Ganglia, SM. G—Superior Mesentric Ganglia, IM. G.—Inferior Mesentric Ganglia.

(b) *Seventh Cranial Nerve* : The cells of origin is in the dorsal nucleus of facial (7th) nerve nucleus which is situated in the lower part of the pons or in the upper part of the medulla.

The pre-ganglionic fibres end in two ganglia : (1) Mackel's *Spheno-palatine ganglia* : The post-ganglionic fibres supply the following structures : (i) The vasodilator fibres to the mucous membrane of nose and palate. (ii) Secretory fibres to the lacrimal gland. (2) *Sub-mandibular ganglia or Langley's ganglia* : The post-ganglionic fibres supply the vaso-dilator and secretory fibre to the sub-lingual gland.

(c) *Nineth Cranial Nerve* : The cell of origin is in the dorsal nucleus or Inferior salivary nucleus of glosso-pharyngeal nerve (9th) which is situated in the medulla oblongata. The pre-ganglionic fibres end in *Otic ganglia*. The post-ganglionic fibres supply the secretory and vaso-dilator fibre to the parotid gland and the mucous membrane of the mouth.

(d) *Tenth Cranial Nerve* : The cell of origin is in the dorsal nucleus of the vagus which is situated in the medulla oblongata. The pre-ganglionic fibres relay in the different ganglia situated close to the organ supplied by the vagus nerve. The post-ganglionic fibre originates from this ganglia and supply the following : (1) Inhibitory fibres to the muscles of the heart. (2) Vaso-constrictor fibres to the coronary vessels. (3) Motor fibres totrachea, bronchous, oesophagus, stomach, small intestine and large intestine upto the junction of right 2/3rd and left 1/3rd. (4) Inbibitory fibres to pyloric and ileocaecal sphincters. (5) Secretory fibres to gastric glands, pancreatic glands and Islets of Langerhans. (6) Motor fibres to the plain muscles of stomach and intestinal wall. (7) Secreto-motor and vasodilator fibres to the pancreas. (8) The fibres which are supplied to the liver, gall bladder and kidney, the action on stimulation is not known. (9) The fibres supplied to the caecum.

[B] **Sacral Outflow** : The cells of origin are on the lateral horn cells of 2nd, 3rd and 4th sacral segments. The preganglionic fibres come out through the anterior nerve root and join together to form a single nerve trunk known as *Pelvic Splanchnic Nerve* or *Nervi Erigentis* and end in the hypogastric ganglia situated close to the organ supplied by these nerves. The post-ganglionic fibres supply the following structures : (1) Vaso-dilator fibre to the blood vessels of genital organ like penis. (2) Motor fibres to the detrusor muscles of the urinary bladder and lower portion of large intestine. (3) Inhibitory fibre to the internal urethral sphincters and anal sphincters. (4) Motor fibres to the plane muscles of the prostate.

Functions : The electrical stimulation of parasympathetic fibre will produce the following symptoms : (1) Constriction of pupil. (2) Slowing of the heart rate with fall of blood pressure and diminished cardiac output. (3) Profuse secretion of digestive juice from different digestive glands. (4) Increased peristaltic movement of stomach, intestine and relaxation of sphincters. (5) Contraction of the ciliary muscles of eyeball. (6) Secretion of tears due to the stimulation of lacrimal gland. (7) Dilatation of all the blood vessels of the body with the exception of coronary vessels which will be constricted. (8) Contraction of the gall bladder. (9) Contraction of the detrusor muscles of the urinary bladder. (10) Increased secretion of saliva from different salivary glands and the saliva will rich in enzyme. (11) Contraction of the plain muscles of trachea, bronchous and broncheoles.

II. **Sympathetic System** : This system is one of the part of autonomic nervous system which as catabolic in function.

Origin : The sympathetic system is known as thoraco-lumbar system. The sympathetic fibres arise from the lateral horn cells of all the thoracic vertebrae and 1st, 2nd and 3rd lumbar vertebrae. The sympathetic fibres after origin will relay in the different sympathetic ganglia like vertebral ganglia, pre-verbebral ganglia and terminal ganglia.

Course with Distributions :

(a) *Sympathetic nerves for Head and Neck* ; It originates from lateral horn cells of 1st and 2nd thoracic segments of spinal cord. The pre-ganglionic fibre relay in the superior cervical ganglia. The post-ganglionic fibre supply the following structures : (1) Vasoconstrictor fibres to the blood vessels of head and neck. (2) Secretory and Vaso-constrictor fibres to the salivary glands. (3) Secretory fibres to the thyroid and lacrimal glands. (4) Dilator pupillae of iris and motor fibres to lateral muscle and muscles of Muller. (5) Secretory fibres to sweat glands to the head and neck and pilomotor nerves to arrector pili muscle of skin.

(b) *Sympathetic nerves for Thoracic Viscera* : It originates from lateral horn cells of 3rd and 4th thoracic segments of the spinal cord. The pre-ganglionic fibres relay in : (1) In case of man—superior, middle and inferior cervical ganglia. (2) In case of lower animals—stellate ganglia formed by the fusion of Inferior cervical ganglia and 1st and 2nd Thoracic ganglia. The post-ganglionic fibres supply the following : (i) Accelerator and augmentor fibres to the heart. (ii) Inhibitory fibres to trachea, bronchous and oesophagus. (iii) Constrictor fibres to the pulmonary vessels. (iv) Vaso-dilator fibres to the coronary vessels.

(c) *Sympathetic Nerves for Fore-limbs* : It originates from lateral horn cells from 5th to 9th thoracic segment of the spinal cord. The pre-ganglionic fibre relay in middle and inferior cervical glanglia and 1st and 2nd thoracic ganglia. The post-ganglionic fibres supply the following: (1) Vaso-constrictor fibres to the cutaneous blood vessels. (2) Secretory fibres to the sweat glands. (3) Pilo-motor fibres to the arrector pili muscles of skin.

(d) *Sympathetic Nerves for Abdominal Viscera*: It originates from lateral horn cells of 6th to 12th thoracic segments of the spinal cord. The pre-ganglionic fibre relay in *Coeliac* and *Superior Mesentricganglia*. The post-ganglionic fibres supply the following: (1) Constrictor fibres to blood vessels of abdomen. (2) Inhibitory fibres to stomach, pancreas, small intestine and large intestine upto the junction of Right 2/3rd and Left 1/3rd of transverse colon. (3) Motor fibres to the spleen and ileo-coelic and pyloric sphincters. (4) Secretory fibres to the supra-renal medulla. (5) Motor fibres to liver for mobilising glycogen and gall bladder.

(e) *Symphathetic Nerves for Hind-Limbs*: It originates from lateral horn cells of 10th thoracic to 2nd lumbar segments of the spinal cord. The pre-ganglionic fibres relay in the *Lumbar* and *Sacral ganglia*. The post-ganglionic fibres supply the muscles of the blood vessels and the structures of the skin.

(f) *Sympathetic Nerves for Pelvic Viscera*: It originates from lateral horn cells of 1st and 2nd lumbar segments of the spinal cord. The pre-ganglionic fibre relay in: (i) Inferior Mesentric ganglia in case of lower animals. (ii) Hypogastric ganglia in case of man. The post-ganglionic fibre supply the following: (1) Vaso-constrictor fibres to the blood vessels of pelvic viscera. (2) Motor fibres to the internal urethral sphincters. (3) Inhibitory fibres to the muscles of the urinary bladder and rest of the Large gut. (4) Both motor and inhibitory fibres to the uterus, uterine tube and ureter. (5) Motor fibres to the muscles of vas deferens and seminal vesicles.

(g) *Sympathetic Nerves for Thoracic and Abdominal wall*: It originates from lateral horn cells from 3rd to 12th thoracic segments of the spinal cord and relay in the thoracic ganglia. The post-ganglionic fibre supply the following: (1) Vaso-constrictor fibres to the blood vessels. (2) Secretory fibres to the sweat glands. (3) Motor fibres to the arrector pili muscles of the skin.

Functions: The electrical stimulation of sympathetic fibres will produce the following manifestations: (1) Dilatation of pupil. (2) Increased force and frequency of the heart with rise of blood pressure. (3) There will be vaso-constriction with the exception of coronary vessels and skeletal vessels. (4) There will be inhibition of a peristaltic movement of stomach and intestine with contraction of sphincters. (5) Secretion of tear from the lacrimal gland of the eyeball. (6) Scanty secretion of saliva from the salivary glands. (7) Secrction of Thyroxine from the Thyroid gland. (8) Relaxation of the plane muscle of trachea, bronchous and oesophagus. (9) Inhibition of the movement of the gall bladder. (10) There will be breakdown of liver glycogen into glucose. (11) Secretion of adrenaline and nor-adrenaline from the supra-renal medulla. (12) Erection of the hairs due to the contraction of arrector pili muscles of the skin. (13) Secretion of sweat glands. (14) Stimulation of glycogenolysis in the liver leading to hyperglycaemia causing increased blood sugar level.

Q. 35. Describe the Cranial nerves with their origin, Distributions and Functions.

The nerves which arise from the brain and come out through the aperture on the cranium are known as cranial nerves. The cranial nerves innervate the anterior and part of the middle region of the body by their branches. These cranial nerves are Olfactory (1st), Optic (2nd), Oculomotor (3rd), Trochlear (4th), Trigeminal (5th), Abducens (6th), Facial (7th), Vestibulo-Cochlear or Acoustic (8th), Glossopharyngeal (9th), Vagus (10th), Spinal accessory (11th) and Hypoglossal (12th) [Fig. 35]

The cranial nerves are of different nature being purely sensory, purely motor or mixed. The olfactory, optic and vestibulocochlear are *sensory* in function, the hypoglossal and spinal accessory are *motor* in function and the oculomotor, trochlear, trigeminal, abducens, facial, glossopharyngeal and Vagus are mixed i.e. motor and sensory in functions. The origin, distribution and functions of the individual cranial nerve are discussed as follows :

I. **Olfactory** : It originates from the nasal mucous membrane and supplies olfactory epithelium cells. It serves the function of sense of smell.

II. **Optic** : It originates from the ganglionic cell layer of retina and supplies the different structures of retina. It serves visual sensation.

III. **Oculomotor** : The cells of origin is in the third cranial nerve nucleus, mesencephalic nucleus of trigeminal nerve and Edinger-Westphal nucleus. It supplies (1) Medial rectus and inferior oblique muscles. (2) Ciliary muscles. (3) Sphincter pupillae, Levator muscle of upper eyelid and superior rectus muscle of eye ball. It serves the functions of : (1) Movement of the eyeball. (2) Proprioception of the muscles of the eyeball. (3) Contraction of pupil and accommodation.

IV. **Trochlear** : The cells of origin are in the mesencephalic nucleus of trigeminal nerve and bipolar cells and fourth cranial nerve nucleus. It supplies superior oblique muscle of eye ball and serves the function of proprioception of superior oblique muscle and movements of eye ball.

V. **Trigeminal** : The cells of origin are the motor nucleus and mesencephalic nuclei of cranial nerve and trigeminal ganglia. It supplies (1) Pinna of the ear, lower part of the face, teeth and gums of the mandible. (2) Cornea, ciliary body and iris, lacrimal gland, conjunctiva, skin of eyelid, eyebrow, forehead and nose. (3) Duramater, forehead, lower eyelid, upper lip, teeth of upper jaw, skin and mucous membrane of cheek and nose. (4) Muscles of mastication and mucous membrane of the anterior part of the tongue. It serves following functions : (1) Movement of mandible. (2) Painful and thermal sensibility of skin, of face and scalp, mucous membrane of nose and mouth. (3) Tactile and pressure sensibility of skin, face and scalp and mucous membrane of nose and mouth. (4) Proprioception of muscles of mastication.

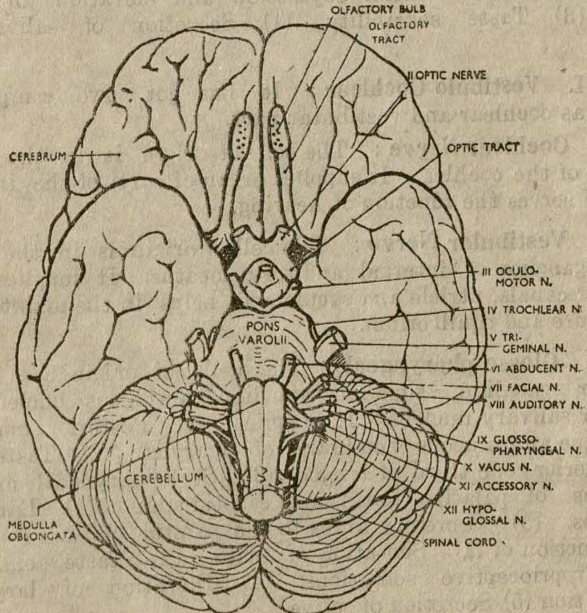


Fig. 35. Diagrammatic representation of the undersurface of the brain showing different cranial nerves.

VI. **Abducens** : The cells of origin are the mesencephalic nucleus of trigeminal nerve and 6th cranial nerve nucleus. It supplies lateral rectus muscle of the eyeball. It serves the function of proprioception of lateral rectus and lateral movement of the eyeball.

VII. **Facial** : The cells of origin are the geniculate ganglion, the cranial nerve nucleus and superior salivary nucleus. It supplies (1) External and middle ear. (2) Muscles of face, neck, pinna and part of face. (3) Taste buds of anterior two-thirds of tongue. (4) Sublingual, submaxillary salivary glands and lacrimal glands. It serves (1) Proprioceptive function. (2) Facial expression and elevation of hyoid bone. (3) Taste sensibility. (4) Secretion of saliva and tear.

VIII. **Vestibulo-Cochlear** : It has got two components known as cochlear and vestibular part.

(a) **Cochlear Nerve** : The cell of origin is in the spiral ganglia of the cochlea. It supplies organ of corti of the internal ear and serves the function of hearing.

(b) **Vestibular Nerve** : The cell of origin is in the vestibular ganglion of internal auditory meatus. It supplies semicircular canals, utricle and sacule and helps in the maintenance of posture and equilibrium.

IX. **Glosso-pharyngeal** : The cells of origin are in the inferior ganglion, superior ganglion, ambiguus nucleus and inferior salivary nucleus. It supplies (1) Posterior one-third of tongue and mucous membrane of pharynx. (2) Taste buds of posterior one-third of tongue. (3) Stylopharyngeal muscles, muscles of palatine tonsil and carotid sinus. (4) Laryngeal muscles. (5) Secretory fibres to the parotid gland. It serves the function of (1) Sensation of taste. (2) Taste sensibility. (3) Proprioceptive sensations. (4) Elevation of larynx in deglutition (5) Secretion of saliva.

X. **Vagus** ; The cells of origin are in the inferior ganglion, dorsal nucleus of 10th cranial nerve, superior ganglion and Nucleus ambiguus in the medulla. It supplies (1) Mucous membrane of epiglottis. (2) Mucous membrane of larynx, trachea, lungs, oesophagus, stomach, intestine, heart, gall-bladder and aortic body. (3) Muscles of pharyax, larynx, trachea, oesophagus, stomach, small intestine, ascending colon, inhibitory fibres to heart, secretory fibres to gastric and pancreatic glands, trachea, spleen, kidney, liver, pancreas. It serves the functions of (1) Taste sensibility. (2) Sensation of thoraco-abdominal organs and movements of stomach and small intestine. (3) Act of swallowing, phonation, movement of stomach and intestine and visceral reflexes of heart and lung.

XI. **Spinal Accessory** : The cell of origin is in the lateral part of anterior gray column of spinal cord (C1 – C5). It supplies the muscles of neck region and shoulder. It helps in the movements of heart and shoulder.

XII. **Hypoglossal** : The cell of origin is in the hypoglossal nucleus of 12th cranial nerve. It supplies muscles of tongue and helps in the movement of the tongue.

Q. 35. Write Short Notes On :

(1) **Elecetro-Encephalogram (EEG)** : It is a record of the spontaneous electrical activity of the brain done by the electro encephalographic machine with the help of the scalp electrodes through the lead that has been studied in human beings. **Types of Waves** : The electroencephalographic records may be bipolar or monopolar and consists of different types of rhythmic waves such as *Alpha*, *Beta*, *Theta* and *Delta*. **Description of the waves** : (a) **Alpha waves** : These are the most prominent rhythmic potential changes found with eyes closed or in dark, when the brain is in quite rest. This wave disappears when eyes remain open. The rate of the waves are 8 to 14 cycles per second. The amplitude becomes highest and being average 50 microvolts. (b) **Beta waves** : These are usually found in the parietal and frontal regions of the scalp. The rate of the waves are about 14 cycles per second and maximum 60 cycles per second. The amplitude becomes 5 to 10 microvolts. (c) **Theta waves** : These are usually found over the parietal and temporal regions of the brain. The rate of the waves are 4 to 8 cycles per second. The amplitude becomes 10 microvolts. (d) **Delta waves** : These waves occur due to the separation of the cerebral cortex from the reticular activating system. The rate of the waves becomes minimum and 0·5 to 35 cycles per second. The amplitude becomes variable and being 20 to 200 microvolts.

(2) **Knee-jerk** : It is a modified tendon reflex which is a forward jerk of the foot due to the contraction of the vastus medialis and intermedius when a light tap is struck upon the patellar ligament just below the knee, with the quadriceps put under some tension by flexion of the knee. **Cause** : It was thought to be a direct response of the muscle to mechanical stimulation. **Functions** : (1) It provides a very important diagnostic sign in diseases of the spinal cord. (ii) It is a very delicate physiological indicator of the tone of the nerve centres in general.

(3) **Hypothalamus** : The hypothalamus is a composite mass of diencephalic structure, composed of scattered diffused nuclei, situated below the thalamus. **Hypothalamic Nuclei** : The hypothalamic nuclei are the pre-optic area, supra-optic area

tuberal area and mammillary area. **Functions** : (i) It regulates sympathetic nervous system. (ii) It regulates para-sympathetic nervous system. (iii) It regulates normal body temperature. (iv) Hypothalamus is concerned with sleep and centre for emotion. (v) It regulates water balance of the body. (vi) It controls carbohydrate metabolism. (vii) It helps in the process of ovulation. (viii) It regulates personality and social behaviour. (ix) It is concerned with the development of ulcer. (x) It is the centre for appetite, hunger and thirst.

(4) **Internal Capsule** : It is a "V" shaped band of white projection fibres connecting the cerebral cortex of neopallium to different levels of brain stem and spinal cord. **Different Parts** : The internal capsule is divided into an anterior limb, a posterior limb and a genu. The posterior limb constitues lenticulo-thalamic part, retro-lenliform part and sub-lentiform part. **Functions** : (i) It prevents muscular weakness and movements concerning limbs, trunk and face of the opposite side. (ii) It maintains the movement of jaw, tongue and soft plalate of the opposite side. (iii) It prevents the phenomenon of hypertonicity of the muscles.

(5) **Choroid Plexus** : It is a vascular finger like projections found into the four ventricles of the brain, specially found in the lateral ventricle. **Structures** : They are vascular fringe like processes of piamater or tuft of capillaries derived from pial blood vessels, covered by a layer of cells continuous with the ciliated epithelium lining the ventricles. **Functions** : The choroid plexus manufactures cerebro-spinal fluid buffer which serves the functions of : (i) It acts as a fluid buffer. (ii) It regulates the volume of cranial contents constant. (ii) It is the medium through which the waste products of the brain and spinal cord will circulate and thereby performing excretory function. (iv) It protects the brain matter from bacterial infection and serves protective function. (v) It acts as the lymph of the brain. (vi) It acts as an intra-cerebral gill concerning respiration. (vii) It serves hormonal function after absorbing pituitary hormones into the blood. (viii) It maintains intra-cranial pressure.

(6) **Formatio Reticularis** : It is a diffused ill-defined mass of nerve cells and nerve fibres forming a network or reticulm in the central portion of the brain stem. **Formation** : It consists of bulbar reticular formation, ponto-mesencephalic nuclei including the thalamic reticular nuclei. **Functions** : (i) It maintains smooth and purposeful mevements, posture and muscle tone. (ii) It regulates the alertness and wakefulness of the animal by any arousal reaction. (iii) It is considered to be the highest centre for autonomic nervous system. (iv) It

plays in regulation of endocrine functions. (v) It is concerned with the emotional and sex behaviours of the individual. (vi) It helps in the development of learning process. (vii) It controls the normal body temperature. (viii) It regulates the sensitivity of tactile receptors and other sensory receptors like in the retina and cochlea.

(7) **Reflex Action :** A reflex action is an unconscious, involuntary, purely automatic-motor reaction due to a sensory stimulus. The impulse arises from the receptor organs, passes through sensory and intermediate neurones and effects the effector organs via motor neurones. The consciousness appears when the act is over. It is not an wilful action. The reflex action is not possible without reflex arc. It is only restricted to the central nervous system. **Parts of a Reflex arc** : For the production of reflex action, there must be a reflex arc which consists of *Receptors*, *Afferent neurone*, *Intermediate neurone*, *Efferent neurone* and *Effector organs*. **Types of Reflex arc** : The reflex arcs may be of several types which are *Simple reflex arc*, *Intercalated reflex arc*, *Crossed reflex arc* and *Complete reflex arc*. **Characteristics of Reflex actions** : The different types of characteristics or properties of reflex actions are Localisation, Block, Co-ordination, Delay, Fatigue, Refractory period, Summation, Subliminal fringe, Rebound, After discharge, Occlusion, Fractionation, Reciprocal Innervation etc.

(8) **Conditioned Reflex** : A conditioned reflex is an acquired reflex where the cerebral cortex is essential and where training and experience form the basis for the development of reflex process. It is applied to perfectly normal animal and affords objective means of observation of the effects and interaction of the sensory stimuli. **Types of Reflexes** : According to Pavlov, all reflex activities can be divided into *Inborn* or *Unconditioned reflex* and *Acquired* or *Conditioned reflex*. **Characteristics of Conditioned reflex** : There are a number of characteristics or properties of conditioned reflexes which are Specificity, Summation, Irradiation, Inhibition, etc. **Functions** : (1) They play an important part in the secretion of different digestive juices from the different digestive glands. (2) They regulate the behaviour and activity of the individuals or animals. (3) It inhibits the functions of the cerebral cortex. (4) It has got an important value in clinical and psychological medicine.

CHAPTER FOUR

SPECIAL SENSES

Introduction : To live on earth after fighting against the natural enviornment, general sensation are not sufficient enough to serve special information duty and therefore special senses are necessary to do that job. The special sense organs are situated in the special parts of the cranium having special end organs and serve special type of functions of the body. There are four types of special senses like *vision, hearing, taste* and *smell.* The vision and hearing perform distant sensation and taste and smell perform chemical sensation. The end organ of vision is the rods and cones cells which are present in the retina. The end organ of hearing is the organ of Corti which is situated in the cochlear part of the internal ear. The end organ of taste becomes the taste bud which is located on the upper surface of the tongue. The end organ of smell becomes the olfactory cell which is situated in the olfactory epithelium of the nose. The receptor organs of vision and audition are in the group of Teloreceptors or Distant receptors and the receptor organs of taste and smell become in the group of Chemical receptors.

EYE (VISION)

Q. 1. Deseribe the Eye as an optical apparatus.

The eye is a special sense organ, situated in the special part of the cranium i.e. in the orbit and serves the special function of vision. The eye ball is kept in position within the orbit by *rectus* and *oblique muscles* and *retro-bulbar fat.* The eye ball is separated from the bony cavity by a fatty capsule known as *Tenon's capsule.* The whole eye ball is broadly made up of tunics or layers and the refractive materials.

I. Layers of the Eye Ball : The exposed part of the eye ball is enveloped by a thin stratified muccus membrane which is reflected on the inner surface of the eye lids that is known as *Conjunctiva.* The wall of the eye ball consists of three layers or coats from without inwards :

(a) **Outer Fibrous Coat** : It is composed of a dense, fibrous elastic supporting membrane. The anterior 1/6th part is transparent known as *Cornea* and the posterior 5/6th part is opaque and white, known as *Sclera.* The junction between the cornea and sclera

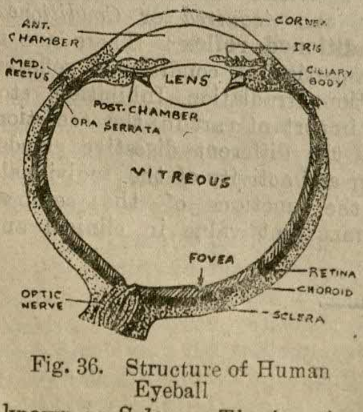


Fig. 36. Structure of Human Eyeball

is called "*Sclero-corneal junction.*" The light rays cannot penitrate through the opaque sclera.

(b) **Middle Vascular Coat**: It is highly vascular and concerned chiefly in the nutrition of the eye. It is also known as *Uveal Tract.* This consists of three parts :

(1) *Anterior Part*: It forms the *Iris* which rests on the lens. In the centre, there is an aperture known as *Pupil.* The pupil helps in the communication between the anterior and posterior chambers of the eye ball and responsible for clear vision.

(2) *Middle Part*: It forms the *Ciliary Body.* It contains *Ciliary Muscle* which is used while seeing near objects. On the inner aspect of the ciliary body, there are numerous projections called the *Ciliary Processes* which secrete aqueous humour from the ciliary blood vessels into the posterior chamber.

(3) *Posterior Part*: It forms the *Choroid* which lies in apposition with the sclera. The function of the choroid is to supply nourishment to the retina which lies on its inner surface.

(c) **Inner Nervous Coat**: The anterior portion forms the lens and its suspensory ligament and the posterior portion forms the *Retina.* It consists of outer pigment layer and inner retina proper. The retina proper contains rods and cones by which we can see.

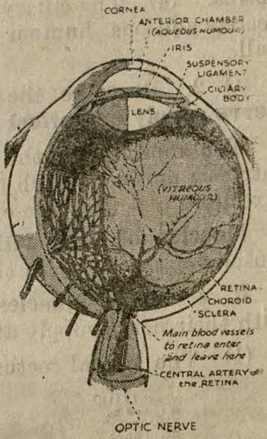

CORNEA
ANTERIOR CHAMBER (AQUEOUS HUMOUR)
IRIS
SUSPENSORY LIGAMENT
CILIARY BODY
LENS
(VITREOUS HUMOUR)
RETINA
CHOROID
SCLERA
Main blood vessels to retina enter and leave here
CENTRAL ARTERY of the RETINA
OPTIC NERVE

Fig. 37. Longitudinal Section of Eyeball showing different Structures, Vessels and Nerves.

II. **Refractive Materials**: There are four refractive media in the eye which help to converge the light rays and focus them on the retina. The refractive media are *Cornea, Aqueous humour, Crystalline lens* and *Vitreous humour.* The lens and the suspensory ligament divide the cavity of the eyeball into a small anterior cavity and a large posterior cavity. The posterior cavity is called the vitreous chamber containg *Vitreous Humour.* The smaller anterior cavity contains *Aqueous Humour* which is further subdivided by the iris into anterior and posterior chambers.

III. **Muscles of the Eye**: There are six external ocular muscles that help in the fixation of eye ball kept in position into the orbit and serves the movement of each eye ball during visualisation of any object. The muscles are grouped into rectus and oblique types. The rectus group of muscles are Superior rectus (Up and In), Inferior rectus (Down and In), Medial rectus or Internal rectus (Inwards) and Lateral rectus or External rectus (Outwards). The oblique group of muscles are Superior oblique (Down and Out) and Ieferior oblique (Up and Out).

IV. Functions of the Eye : (1) Light enters through the transparent cornea and by means of a lens system, an inverted image is formed on a photosensitive retina which converts the light into nerve impulses. These impulses are then relayed to the occipital cortex and are interpreted as sight. (2) The muscles of the eye help to move the accommodation of an object. (3) The choroid helps to supply nourshment to the retina. (4) The ciliary processes of the ciliary body helps to secrete aqueous humour into the anterior chamber of the eye ball.

Q. 2. Describe the different muscles of the Eye, their nerve supply and effect of section.

The muscles of the eye are grouped into extrinsic and intrinsic muscles which help for the movement of eye in different directions and fixes the eye in original position.

Muscles of Eye with their Nerve Supply : The different muscles of the eye with their nerve supply are as follows :

I. Extrinsic Muscles : The extrinsic muscles of the eye with their nerve supply are as follows :

(1) The Medial rectus is supplied by third cranial nerve.

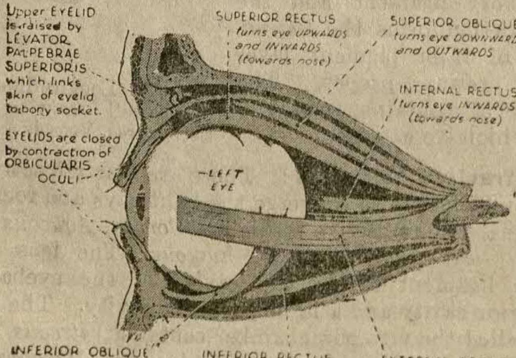

Upper EYELID is raised by LEVATOR PALPEBRAE SUPERIORIS which links skin of eyelid to bony socket.
SUPERIOR RECTUS turns eye UPWARDS and INWARDS (towards nose)
SUPERIOR OBLIQUE turns eye DOWNWARDS and OUTWARDS
INTERNAL RECTUS turns eye INWARDS (towards nose)
EYELIDS are closed by contraction of ORBICULARIS OCULI
LEFT EYE
INFERIOR OBLIQUE
INFERIOR RECTUS
EXTERNAL RECTUS

Fig. 38. Extraocular Muscles with their actions.

(2) The Lateral rectus is supplied by sixth cranial nerve.
(3) The Superior rectus is supplied by third cranial nerve.
(4) The Inferior rectus is supplied by third cranial nerve.

(5) The Superior oblique is supplied by fourth cranial nerve.

(6) The Inferior oblique is supplied by third cranial nerve.

(7) The Levator palpabrae superioris is supplied by seventh cranial nerve.

(8) The muscles of Muller are supplied by sympathetic nerve.

II. **Intrinsic Muscles** : The intrinsic muscles of the eye with their nerve supply are as follows :

(1) The Constrictor pupillae are supplied by third cranial nerve.

(2) The Dilator pupillae are supplied by sympathetic nerve.

(3) The ciliary muscles are supplied by third cranial nerve.

Effects of Section :

(a) **Of Third Cranial Nerve** : (1) Lateral squint or External strabismus will occur due to the paralysis of medial rectus muscle. (2) Diplopia or double vision. (3) Ptosis or drooping of the upper eye lid. (4) Slight protrusion of the eye ball. (5) Loss of Accommodation. (6) Loss of Light reflex. (7) Dilatation of pupil. (8) Inability to move eye ball inwards. The downward and upward movements of eye ball are also restricted.

(b) **Of Fourth Cranial Nerve** : (1) Slight upward deviation of cornea due to the rolling up of the eye ball causing vertical squint. (2) Homonymous diplopia while looking downwards.

(c) **Of Sixth Cranial Nerve** : (1) Medial or Internal strabismus or squint. (2) Homonymous diplopia. (3) Inability to move the eyeball outwards.

(d) **Of Sympathetic Nerve** : It will cause *Horner's Syndrome* producing (1) Constriction of pupil. (2) Enophthalmus. (3) Ptosis or drooping of eye lids. (4) Profuse lacrimation.

Q. 3. Describe the Structure and Functions of Iris and state the causes of constriction and dilatation of Pupil.

Iris is a contactile circular diaphragm hanging behind the cornea and immediately infront of the lens. It has got a central round aperture known as pupil. The iris is attached to the periphery of the ciliary body and free at the surface. The colour of the iris is dark brown colour in Indians. The diameter of the pupil can be altered. The centre of the pupil is exactly against the centre of the lens.

Histology : The iris is an epithelio-musculo-vascular organ, consists of a number of layers which are arranged from backwards :

(a) **Squamous Endothelium** : It consists of flattened squamous endothelial cells placed on a delicate hyaline basement membrane.

(b) **Anterior Elastic Lamina** : It is the condensation of the anterior part of stroma. It contains obliterated blood vessels and numerous nerve endings.

(c) **Stroma or Vessel Layer** : It consists of (1) *Blood vessels.* (2) *Lymphatics.* (3) *Collagen fibres.* (4) *Nerves.* (5) Unstripted muscle fibres forming circular in patten known as *Sphincter pupillae* or *Constrictor pupillae*, (6) *Branched Pigment Cells* containing pigment granules.

(d) **Posterior Lamina** (Membrane of Bruch) : It consists of a thin unstriped plain muscle fibres which are derived from the anterier layer of the optic cup and ectodermal in origin. This layer is radial in arrangement and forms Dilator pupillae when it contracts, pupil dilates.

(e) **Cubical Epithelial Layer** : It is derived form the most anterior part of the optic cup. Its anterior layer consists of flat spindle cells and the posterior layer consists of large polyhedral or cubical cells with relatively small, rounded cells.

Functions of Iris : (1) It regulates the amount of light falling on the retina. It darknses the pupil dilates and in bright light, the pupil contracts and allows the central ray to pass. (2) It prevents the entrance of loss refracted peripheral rays. (3) It prevents chromatic and spherical aberration due to less refracted peripheral rays. (4) It increases the depth of focus of the lens of the eye which is of great value for near vision.

Causes of Constriction of Pupil : (1) When light falls on the retina as Light reflex. (2) Adjust the eye to near vision during accommodation. (3) Stimulation on of 3rd cranial nerve or short ciliary nerve. (4) Lesion of cervical sympathetic nerve. (5) Use of myotic drugs like Morphine, Opium, Pilocarpine, Eserine, Physostigmine etc. (6) During sleep causing depression of sympathetic action. (7) During induction of inhalation of anaesthetics like ether, chloroform etc. (8) During pontine haemorrhage, intracranial pressure is increased causing pin-point pupil. (9) In head injury such as in concussion and compression of the brain. (10) In horner's syndrome, there will be constriction of pupil.

Causes of Dilatation of Pupil : (1) When eyes are exposed to darkness. (2) When eyes are fixed to a distant object because iris accommodates for distant vision. (3) Stimulation of cervical sympathetic ganglia or fibres. (4) Use of Mydriatics drugs like Atropine, Homatropine, Adrenaline, Cocaine etc. (5) During anxiety, fear, emotional state and excitement. (6) Exhaustion of central nervous system or deep anaesthesia. (7) In third stage of Asphyxia. (8) Increased intra-ocular pressure as in Glaucoma. (9) Hyperactivity of Thyroid gland (Hyperthyroidism) and Adrenal or Supra-renal medulla (Hyperadrenalism). (10) During concussion and compression of brain as in head injury. (11) Section or paralysis of 3rd cranial nerve.

Q. 4. Describe the Structure and Composition of Lens.

The crystalline lens is a transparent biconvex structure and the convexity increases as age advances. The posterior surface is more convex than the anterior. The lens is covered by a capsule which is thicker at the periphery but thinner at the centre. It is kept in position by suspensory ligment known as *Zonule of zinn* and a prolongation of hyaloid membrane. The centre of the anterior surface of the lens is called the *anterior pole* and the centre of the posterior surface of the lens is called the *posterior pole*. The line joining these two poles is called the *axis* of the lens. The two surfaces of the lens meet at the periphery in a rounded margin known as *Equator* of the lens. The main function of lens is refraction of light rays. The refractive index is 1·41 at the centre and 1·37 at the periphery.

Histology : The lens is enveloped by an elastic capsule, the poterior part is thinner but towards the periphery, it is thicker. Just under the anterior capsule, there is a single layer of columnar epithelium. The lens is composed of innumerable fibres arranged in layers like the scales of an onion. The central part of the lens in more firm forming *nucleus* and the peripheral part forms the *cortex*.

Composition of Lens : The lens is composed of 65% water and 35% solids. The amount of water increases as lens grows and in old age, it decreases. The substances are organic, inorganic and other substances.

(a) **Organic Substances** : (1) *Proteins* (33%) : Euglobin or albuminoid (17%), Pseudoglobulins, α—Crystalline (11%), β—Crystalline (6%), Albumin (0·2%), Mucoprotein, Nucleoprotein etc. (2) *Lipids* : Phospholipids, Cholesterol etc.

(b) **Inorganic Substances :** The lens substance contains Potassium, Calcium, Sodium, Magnesium, Chloride, Phosphates, Sulphates, Silicates, etc.

(c) **Other Substances** : These substances are very negligible which are : (1) Ascorbic acid—both oxidised and reduced form. (2) Glutathione. (3) Oxidative Enzymes—Thiamine (B_1), Riboflavin, Cytochrome oxidase, etc.

Q. 5. Describe the Refractive Media of the eye.

The inverted images of external objects are formed exactly on the retina, passes through the optic nerves and reaches into the occipital brain where visual impressions are produced. There are four refractive media in the eye which help to converge the light rays and fall on the retina. The refractive media of the eye are Cornea, Aqueous humour, Lens and the Vitreous humour.

I. **Cornea** : The cornea is a clear, thin, avascular anterior transparent part of eye ball. It is continued behind as sclera and its junction is called sclero-corneal junction. It is circular in outline and its anterior part is convex. Its average diameter being approximately 11 mm. and 0·5 to 1 mm. in thickness. It gets nutrition from lymph and aqueous humour. The cornea is composed of five layers such as corneal epithelium, Bowman's membrane, substantia propria, Descemet's membrane and endothelium.

II. **Aqueous Humour** : It is a clear, thin watery intraocular fluid occupies the anterior and posterior chambers of the eye. The two chambers communicate through the pupil. It is derived from the blood plasma and is secreted into two posterior chambers from the vessels of iris and the ciliary processes.

III. **Lens** : It is a transparent biconvex structure and the convexity increases as age advances. The porterior surface is more convex than the anterior. The lens is covered by a capsule. It is kept in position by suspensory ligament known as *Zonula of Zinn* and a prolongation of hyaloid membrane. The main function of the lens is refraction of light rays. The refractive index is 1·41 at the centre and 1·37 at the periphery.

IV. **Vitreous Humour** : It is a jelley-like material covered by a homogeneous membrane known as hyaloid membrane. It occupies the posterior compartment of the eyeball. A canal passes through vitreous humour which extends from the centre of the posterior surface of the lens upto the centre of the disc. Its important function is to help in the refraction of light and to maintain the shape of eyeball. Its refractive index is 1·34.

Q. 6. Describe the Structure of Retina with Regional pecularities. Discuss the functions of Retina.

The retina is a photosensitive organ lies in the innermost coat of the eyeball. It has a complex structure and contains sensitive of light, nerve cells and supporting structures.

Structure of Retina : (Fig. 40) The retina consists of ten layers—one is pigment layer, two are limiting membranes and the rest seven layers are nervous in structure. The structure of the retina is described from without inwards and composed of following layers :

(1) **Pigment Cell Layer :** It consists of single row of

large hexagonal epithelial cells containing rod-shaped granules of a dark brown melanin like pigment called as *Fuchsin*.

(2) **Layer of Rods and Cones** : The rod and cone cells are the visual receptors. They lie with their axes perpendicular to the visual surface. The *rod cell* are 40 to 50 μ long and consists of outer and inner segments. The *cone cell* is situated towards the central part of the retina and its length varies from 28 to 85 μ. The cone cell is divided into two segments—outer and inner segment.

(3) **External Limiting Membrane :** This is composed of the fine felt-network of the lateral processes of the radially arranged glial fibres at the bases of the rods and cones.

(4) **Outer Nuclear Layer** : This layer is composed of cone granules and cone fibres and rod granules and rod fibres. They constitute the first order neurone in the visual path.

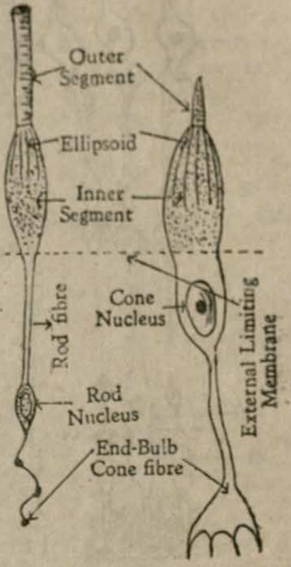


Fig. 39. Structural Parts of a retinal rod (on the left) and and cone (on the right).

(5) **External Plexiform Layer** : It is made up of the ramifications of the process of bipolar and horizontal cells of the inner nuclear layer and the terminations of rod fibres and cone fibres.

(6) **Internal Nuclear Layer** : This layer contains three types of cells known as *Bipolar cells*, *Horizontal cells* and *Amacrine cells.*

(7) **Internal Plexiform Layer** : This layer is made up of the dendrons of the ganglion cells and the processes of the ganglion cells and the processes of the bipolar cells and the amacrine cells of the inner nuclear layer.

(8) **Ganglion Cell Layer** : These are large flask-shaped cells and their dedrons form the internal plexiform layer and their axon, as optic nerve fibres terminate in the stratum opticum. The cells contain nuclei and chromatin granules.

(9) **Stratum Opticum or Optical Nerve fibre Layer :** This layer is composed of axons of ganglion cell which form the optic nerve fibers. The retinal blood vessels are present here.

(10) **Internal Limiting Membrane** : This is composed of fibrous tissue and separate the retina from vitreous humour. It is formed by the apposition of the glial fibres.

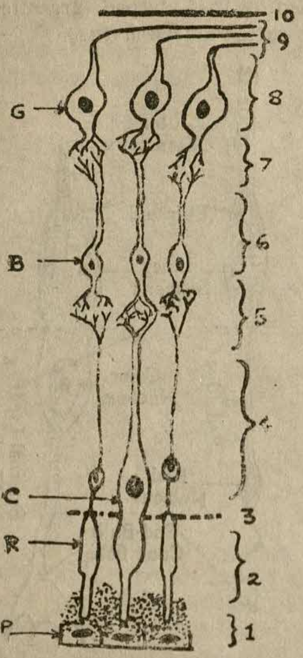


Fig. 40
Different Layers of Retina. G—Ganglionic Cell, B—Bipolar Cell, C—Cone Cell, R—Rod Cell, P—Pigment Cell, 1 to 10—Different layers of retina.

Regional Peculiarities : The rods are arranged towards the periphery of the retina and cones are arranged towards the central part of the retina. In the posterior part of the retina there are two regions with certain structural peculiarities.

(a) **Peripheral Retina** : The rods are chiefly present on the peripheral part of the retina. The cones diminish and rods increase in number from the fovea to the periphery. So, in the peripheral part of the retina, only twilight vision is possible but no colour vision.

(b) **Optic Disc or Blind Spot** : It is situated about 3 m.m. to the nasal side and a little above the posterior pole of the eye ball. The optic disc is totally insensitive to light because it does not contain any receptors i.e. neither cones nor rods. The optic nerves will come out through this spot of the retina.

(c) **Macula Lutea or Yellow Spot** : It is a small diffused yellow area seen in the retina, situated about 3·5 m.m. from the outer edge of the optic disc. In the macula lutea, there are both rods and cones and in the centre of macula lutea, there is a depression known as *Fovea centralis*,

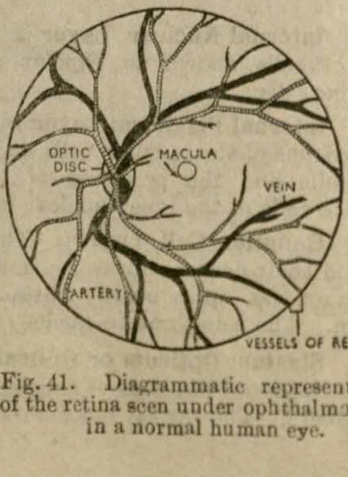


Fig. 41. Diagrammatic representation of the retina seen under ophthalmoscope in a normal human eye.

where there is maximum concentration of the cones.

Functions of Retina : The following are the functions of the retina : (1) The rods are responsible for dimlight vision and peripheral vision. The chemical substance known as visual purple present in rods for dimlight vision. (2) The cones are responsible for bright light vision, colour vision and acquity of vision. The macula lutea contains both rods and cones which are responsible both for dimlight and bright light vision. (4) The blind spot of retina is known as optic disc which is devoid of visual receptors and there will be no vision.

Q. 7. Describe the changes that take place in the retina on exposure to light.

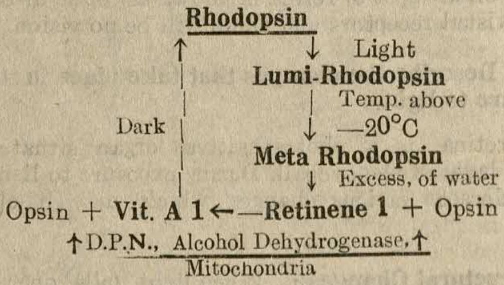
The retina is a photosensitive organ situated at the innermost layer of the eyeball. During exposure to light stimulus retina undergoes various changes which may be classified as follows :

I. **Structural Changes** : When light falls on retina, the different structural chagnes are localised which are : (1) There will be shortenings of the outer segment of the cones. (2) There will be swelling of the outer segment of the rods. (3) The visual pigments from the pigmented cell will migrate in between the rods and cones. (4) There will be breakdown and disappearance of the chromatin granules present in the ganglion cells of retina.

II. **Photo-Chemical Changes** : When light falls on the retina, there will be bleaching of the pigments, fuchsin and visual purple. The pigment, visual purple will be converted first into visual yellow and then into visual white. The retina becomes acidic due to the accumulation of latic acid and carbonic acid.

(a) **Fuchsin** : It is the pigment found in the processes of the pigment cell layer as needles, plates or prisms. Strong light causes some degree of bleaching.

(b) **Rhodopsin** : On exposure to light on rods, it produces *Rhodopsin* and *Prophyropsin* after bleaching. At first it breaks down into a carotenoid yellow pigment, *Retinene* and a *Protein.* Retinene then becomes converted into a colourless *Visual white.* The basic mechanism of Rhodopsin synthesis is the energy demanding oxidation of Vitamin A to Retinene coupled with the energy yielding condensation of Retinene and Opsin to form Rhodopsin. The Rhodopsin is converted by light to orange red intermediate known as *Lumi-Rhodopsin* which then forms *Meta-Rhodopsin* by temperature above—20°C and ultimately with excess of water yields Retinene 1 and Opsin. The Retinene 1 is then reduced to *Vitamin* A_1 by enzyme *alcohol dehydrogenase* in presence of NAD. Vitamin A_1 is then stored in the pigment epithelium. The retinene 1 is *trans* isomer whereas the retinene of rhodopsin is 11-cis isomer. In the dark, the spontaneous combination of Retinene 1 and Opsin to form Rhodopsin promotes the oxidation of Vitamin A_1 to Retinene. This process is aided by provision of D.P.N, the oxidant of Vitamin A, mitochodria and alcohol dehydrogenase. The Rhodopsin cycle is as follows :



(Kreb's Cycle)

(c) **Iodopsin** : It is a photosensitive pigment, present in cone cells. It is a violet pigment identical with the Rhodopsin system. The Coneopsins are called *Photopsin*. Rhodopsin combines with Neo B Retenene 1 to produce Rhodopsin or with Neo B Retinene 2 to yield *Porphyropsin*. Coneopsin similarly combines with *Neo* B Retinene 1 to yield Iodopsin.

III. **Physiological Changes** : (1) The cones are responsible for bright light vision, colour vision and acquity of vision. The cones are arranged towards the central part of the retina and the maximum concentration of the cone is in the fovea centralis which is the central depression area of the Macula lutea. (2) The rods are responsible for dimlight vision. The resynthesis of visual purple or Rhodopsin from visual white with the help of vitamin A is actually responsible for the dimlight vision. (3) In the *macula lutea*, both rods and cones are present and therefore responsible both for dimlight and bright light vision. (4) In *fovea centralis*, cones are only present and therefore they are resposible only for bright light vision. (5) In the blind spot or *Optic disc* of the retina, there are no visual receptors and therefore this particular spot is devoid of any visual sensations.

IV. **Electrical Changes** : When light falls on retina, electrical changes known as Action Potential changes will occur in the retina. This electrical changes can be recorded with the help of the instrument, known as "Electro-Retinograph" and the record is known as "Electro-Retinogram" or E. R. G. The

Electro-retinogram consists of four waves, designated as a, b, c and d. The '*a*' *wave* is small, rapid and negative deflection. The '*b*' *wave* is well marked and positive. The '*c*' *wave* is slow, prolonged and positive wave. The '*d*' *wave* is small positive wave which appears after a brief latency when the light is cut off and for this reason it is usually referred to "*Off Effect*".

Q. 8. Describe the Visual Path or Path of Vision :

The retina is the photosensitive organ. It possesses photoreceptors which are known as rods and cones. They receive light impulses which passes through the optic nerve and ultimately reaches into the occipital visual cortex by which we can see and serves our visual function. The visual path consists of visual sensations and visual reflexes.

I. **Visual Sensations** : The visual impulses from the retina will pass through optic nerve which will come out through the blind spot of the retina. The optic nerve traverses backwards and after traversing for a short distance, the nasal fibres will decussate and temporal fibres will remain uncrossed.

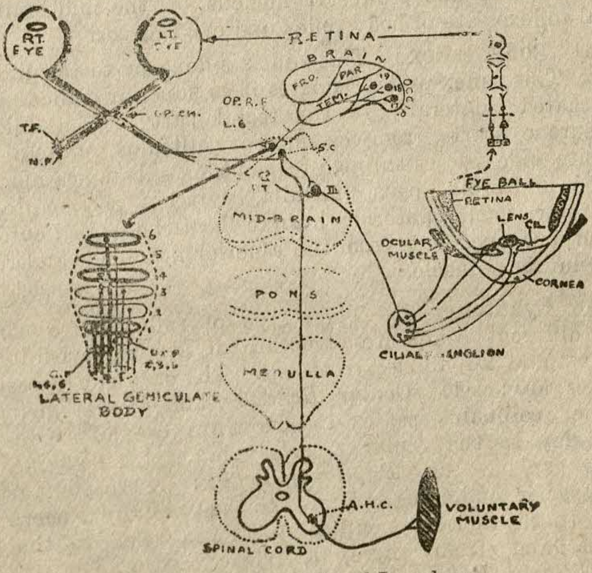


Fig. 42. Path of Visual Impulses.

T. F—Temporal Fibre, N. F—Nasal Fibre, OP. CH—Optic Chiasma, OP. R. F—Optic Radiation Fibre, L. G—Lateral Geniculate body, S. C—Superior Collicullar Structure, P. T—Pre-tectal Nucleus, III—3rd. Cranial Nucleus, C.F—Crossed Fibres, U.C.F—Uncrossed Fibres, O. T—Optic Tract, CIL.—Ciliary body, A. H. C—Anterior Horn Cell.

This decussation is known as *optic chiasma.* After the optic chiasma, there is a formation of *optic tract* consisting of nasal fibres of the opposite eye and temporal fibres of the same eye. The optic tract will ascend upwards and will relay in either of the three ways : (i) Few fibres will relay in *Pretectal area* which is the centre of light reflex. (2) Few fibres will relay in *Superior cilliculus* which is to be concerned for visual reflexes. (3) Most of the fibres carrying visual sensation which will relay in *Lateral geniculate body.* In the lateral geniculate body, there are six cell layers. The nasal fibres will relay in 1st, 4th and 6th cell layers and the temporal fibres will relay in 2nd, 3rd and 5th cell layers. From the lateral geniculate body, fresh fibres arise which will terminate in the *Visuo-Sensory area* or Area no. 17 in the occipital lobe of the cerebral cortex, as *optic radiation* fibre passing through the *posterior 1/3rd* of the *posterior limb of the internal capsule.*

II. **Visual Reflexes** : These reflexes arises from the superior colliculus and pre-tectal nucleus of the mid-brain. The visual reflexes are of body reflex and eye reflexes.

(a) **Body Reflex** : This reflex is done by tecto-spinal tract reflex. This reflex path originates from superior colliculus which is situated bilaterally in the tectal part of the mid-brain. A neurone starts from the superior colliculus, crosses to the opposite side, passes through tegmentum, substantia nigra, crus of the mid-brain, pons, medulla, pyramid portion of medulla and relay to the anterior horn cell of the spinal cord. The second neurone starts from the anierior horn cells and relay to the voluntary muscle.

(b) **Eye Reflexes** : These type of reflexes are concerned with different composite structure of eye ball with its neighbouring and adjoining structures. The different types of eye reflexes are : (1) *Ocular Reflex* : The fibres arising from superior colliculus passes to the third cranial nerve nuclei and relay to the ocular muscles via short ciliary nerve and ciliary ganglia. (2) *Pupillary Reflex* : A process starts from the superior colliculus and relay to the 3rd cranial nerve nuclei. From there, another neurone starts and relay to the ciliary ganglia and from there, it relays to the pupillary area. (3) *Ciliary Reflex* : A process starts from the superior colliculus and relay to the 3rd cranial nerve nuclei. From there another neurone starts and relay to the ciliary ganglia and from there, it will relay to the ciliary muscle as short ciliary nerve. (4) *Accommodation Reflex* : A process starts from superior colliculus and relay to the 3rd cranial nerve nuclei. Another neurone starts from there and relay to the ciliary ganglia. From there, the next neurone starts and relay to the cornea, ciliary muscle, pupil as short ciliary nerves. (5) *Light*

Reflex: A process starts from the pre-tectal nucleus which is situated in the tegmental part of the mid-brain and relay in the 3rd cranial nerve nuclei of the opposite side. From there, another neurone starts and relay to the ciliary ganglia. The third neurone starts from the ciliary ganglia and relay to the cornea, pupil and ocular muscles as short cilary nerve.

Q. 9. Describe the path of of Light Reflex. What do you mean by Argyll Robertson Pupil ?

It is seen that when light falls on the retina, pupil contracts even to a pin point of the same side. This is known as *Light reflex* and is determined by the contraction of sphincter pupillae together with a relaxation of the dilator muscle. This takes place involuntarily and unconsciously.

Path of Light Reflex : It consists of afferent path, centre and efferent path.

(a) **Afferent Fibres** : These consitute optic nerve fibres which originate from stratum opticum in the retina. The nasal fibres decussate with each other at the chiasma, pass to the opposite optic tract and occupy the central part of the chiasma. The temporal fibres of the optic nerve do not decussate but they pass to the optic tract of the same side and occupy the lateral portion of the optic chiasma. The optic tract now containing fibres of the temporal half of the same side and nasal half of the opposite side, winds round the cerebral peduncle and descend upto the lateral geniculate body. The afferent fibres which take part in this reflex do not end in the lateral geniculate body, but proceed to a group of cells in the pre-tectal region i.e. in the pre-tectal nucleus where they take first relay. The impulses are finally conveyed by secondary neurones to the third cranial nerve nuclei.

(b) **Centre** : The centre of light reflex is the *Edinger Westphal nucleus* of the 3rd nerve of the opposite side.

(c) **Efferent Fibres** : These belong to the parasympathetic divisions of the autonomic nervous system. They originate in the Edinger Westphal nucleus and are conveyed to the sphincter pupillae of the iris via the occulomotor nerve, ciliary ganglion and short ciliary nerves.

Argyll Robertson Pupil : It is a condition of the pupil when light reflex is lost but accommodation reflex persists. This is due to the destruction of pae-tectal area or section of colliculo-nuclear fibres which is commonly found in cerebral syphilis,

Q. 10. What is Accommodation ? Describe the path of Accommodation and the mechanism or change during accommodation.

Accommodation is an adjustment of the dioptrics of the eye to the images of far and near objects. When light falls on the eye, the major part of it passes through the ocular media to strike the retina is called dioptric image.

Path of Accommodation : It consists of affenent path, centre and efferent path.

(a) **Afferent Path** : It constitutes optic nerve fibres which originate from the axonic processes of the ganglionic cells of the retina. The crossed nasal and uncrosed temporal fibres form the optic chiasma. The optic tract now containing fibres of the temporal half of the same side and nasal half of the opposite side, winds round the cerebral peduncle and descend upto lateral geniculate body. From there, another neurone starts, passes through the posterior limb of the internal capsule and relay to the visuo-sensory area (Area 17) of the occipital cortex as optic radiation fibre. A neurone starts from there and relay to the frontal eye field area (Area 8) of the frontal lobe of the cerebral cortex. From area 8, cortico-nuclear fibre arises, passes through the anterior limb of the internal capsule and relay to the 3rd cranial nerve nuclei.

(b) **Centre** : The centre for accommodation path is the Edinger Westphal nucleus of the 3rd nerve of the opposite side.

(c) **Efferent Path** : It starts from the 3rd nerve nuclei of the opposite side and relay to the ciliary ganglia. From there, post-ganglionic fibre arises as short ciliary nerve and relay to the sphincter pupillae and ciliary muscle.

Mechanism or Changes during Accommodation :

(a) *Increased convexity of the anterior surface of the Lens* : It is caused by relaxation of the suspensory ligament which is brought about by the contraction of the ciliary muscles supplied by the 3rd nerve and the object being to clearly focus near objects. The increased convexity of the anterior surface of lens will increase the focal length of eyeball so that the parallel rays from the objects can converge on the retina to give the clear vision.

(b) *Internal convergence of the Eye ball* : This is due to contraction of the internal recti muscles supplied by 3rd nerve. By this, convergence objects are focussed on the identical points of both the retinae and thus a double vision i. e., diplopia is prevented.

(c) *Constriction of the Pupil* : This occurs because of the constriction of the sphincter pupillae muscles supplied by 3rd nerve. By this action, peripheral rays are cut off and thus the clearness of the image on the retina is increased.

Q. 11. Describe the Common Errors of Refraction or Defects of Vision and how they are corrected ?

Eye, the optical apparatus of the human being, serves the function of normal vision and by means of which we can perceive any type of movement and colour object. In certain pathological conditions, this eye converts into a defective one which can be adjusted or corrected by concave, convex and cylindrical lenses.

Errors of Refraction or Defects of Vision : The different types of common errors of refraction of eye are as follows :

I. **Myopia or Short Sightedness** : (can see near objects). In this condition, the eye ball is too long, relatively to its refracting power and the eye will bring the parallel rays to a focus infront of the retina. The patient can see the near objects but cannot see the distant objects. **Cause:** This defect is due to : (1) Abnormal elongation of the eye ball. (2) Increased convexity of the cornea. (3) More accumulation of aqueous humour. (4) Abnormal elongation of the lens on its anterior aspect. (5) The disturbed electrolyte metabolism in diabetes produces osmotic changes in the lens and resulting in changes in the curvature of the lens fibres and of the lens surface that ultimately produce myopia. **Correction** : A short sighted eye can be corrected by the use of *Concave glasses* which diverge the rays entering the eye.

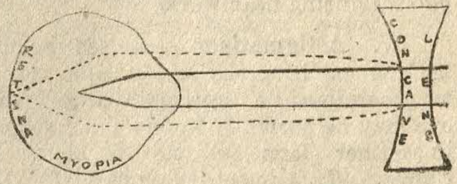


Fig. 43. Myopia corrected by Concave Lens.

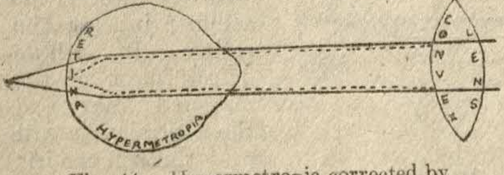


Fig. 44. Hypermetropia corrected by Convex Lens.

II. **Hypermetropia or Long Sightedness** : (can see far objects). In this condition, the eye is too short in its antero-posterior diameter for its refracting power and the parallel rays from near objects will fall behind the retina. The near point in this cases is further away than in the normal eye. In this defect, the patient can see the distant object but cannot see the near object. This type of defect is usually found in young subjects. **Cause** : This defect is due to : (1) Diminished convexity of the cornea. (2) Narrowing of the lens in its antero-posterior diameter. (3) Less formation of aqueous humour. **Correction** : The long sightedness can be corrected by the use of *Convex glasses* which converge the rays entering the eye.

III. **Presbyopia or Old Sightedness** (can not see near objects) : This condition is usually found after the age of forty in normal physiological condition. The person cannot see the near objects but can see the distant objects. The hypermetropic condition above the age of forty is called *Presbyopia* which is due to the loss of power of accommodation because ciliary muscle become weak and elasticity of the lens is less. So, Presbyopia is a modified from of Hypermetropia. **Cause** : It is due to the gradual loss of the power of accommodation due to : (1) Increased density of the lens. (2) Loss of elasticity of the suspensory ligament. (3) Weakness of the ciliary muscles. **Correction** : This defect is corrected by the use of *Weak Convex glasses* during near work.

IV. **Astigmatism** : (can see the object in one plane clearly). In this condition the person cannot see the objects distinctly in two meridians i.e., horizontal and vertical simultaneously. The eye may be normally in one plane and myopic or hypermetropic in another plane and this is known as *Simple Astigmatism*. **Cause** : This defect is due to : (1) Difference in the curvature of the cornea in different places. (2) Inequality of the curvature of the lens. **Correction** : The simple astigmatism is corrected by the *Cylindrical glasses*. The compound astigmatism is corrected by concavo-convex glasses.

V. **Spherical Aberration** : The rays of light passing through the circumference of the lens are refracted more quickly than those passing through the centre of the lens hence the light rays passing through the circumference of the lens and through the centre of the lens will not meet at the same point at the retina. In this defect, most of the marginal rays and the central rays will pass through the iris and one image will be formed upon the other and as a result the vision becomes indistinct. **Cause** : This defect is due to : (1) Decreased refractive power of the lens. (2) Increased refractive index of the lens from the circumference towards the centre. **Correction** : This defect may be corrected by surgical operation in the iris.

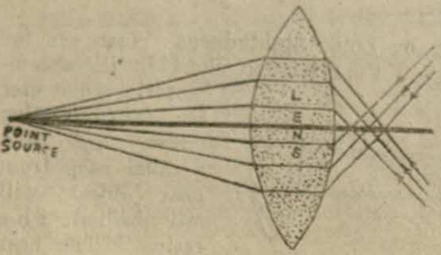


Fig. 45. Spherical Aberration.

VI. **Chromatic Aberration** : The normal eye is achromatic and this condition occurs due to the defect in the refractive media. When the intra-ocular pressure is very high, the white colour is broken down into component colours and the person will see the coloured image or rainbow hallow. In this defect the patient cannot see the white light but will see the seven colours i. e. "Vibgyor". **Cause** : This defect is due to : (1) In case of Glaucoma. (2) Increased intra-ocular tension. **Correction** : This defect is corrected by reducing the intraocular tension either by operation or by drugs.

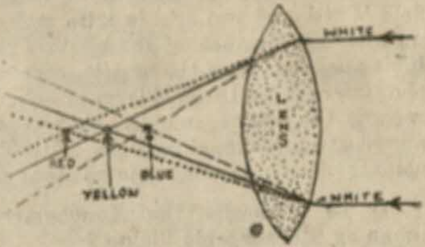


Fig. 46. Chromatic Aberration.

Q 12. Describe the path, conditions necessary and advantages of Binocular vision.

The perception of one object by two eyes is known as Binocular Vision.

Path of Binocular Vision : The rays of light entering the eyes from an object into the binocular field of vision fall upon the nasal field of one retina and upon the temporal half of the other. If, however, the object is well to the right or to the left of the line of vision, i.e. in the outer part of either temporal field the ray then fall upon the nasal half of the peripheral retina of the nearer eye but not upon the other retina which shaded by the nose. So the monocular field of vision consists in man of a concentric area (35°) at the outer limit of the temporal field of each eye.

Conditions Necessary For Binocular Vision : The following conditions should be complied with in concern of binocular vision : (1) The visual field of the two eyes must be overlapped. (2) Approximately similar images must be formed on the two ratinae, antagonism between the images will occur and first one image and then the other will be presented to consciousness. (3) The retinae must possess physiologically corresponding points, so that similar images formed on them may produce one conscious impression. (4) The external ocular muscles contract in such a way that the axis of the eye ball should converge to the object. (5) The oblique muscles move the eye ball in such a fashion that the corresponding physiological points should remain in corresponding meridians.

Advantages of Binocular Vision : Binocular vision or vision with both eyes present the following advantages : (1) The defects of one eye are corrected by other eye. (2) The combined field of vision of two eyes is quite wider. (3) The judgment as regards the distance of an object is rendered more accurate as it is arised at from the muscle sense of the eye muscles chiefly the internal recti and ciliary muscle. (4) The judgement as regards the size of an object that it is height and breadth of an objects is rendered possible. (5) The judgement of depth or solidity of an object is rendered more exact.

Q. 13. Describe the Monocular Vision. What do you mean by Stereoscopic Vision ?

The perception of one eye by the people is known as monocular vision. The individual can appreciate the size, depth and distance of an object.

Factors Concerning Monocular Vision : The monocular vision depends upon the following factors :

(1) *Apparent size and distance of the object* : The greater the distance, the smaller will be the object.

(2) *Apparent colour of the object* : The greater the distance, the change are gradully fade up the colour or disappearance of colour.

(3) *Partial blocking* : The distance of an object is partially blocked by near object.

(4) *Light and Shade* : During shadow, the appreciation of of an object is not perfect.

(5) *Mathematical Perspective* : The parallel rays converge at a distance i.e. railway lines.

(6) *Parallax* : During railway journey, near object is moving in opposite direction and distant object moves towards the movement of the head.

Stereoscopic Vision : The stereoscopic vision is the appreciation of depth, distance, size and shape of three dimentional pictures. This type of vision is nothing but the binocular vision. It is different in light adapted and dark adapted eye.

Q. 14. Describe the Theories of Colour Vision.

The retina, a photosensitive organ of the eye, is useful not only in perception of light but colour is also perceived through the action of different rates of vibrations on the retina specially on the cones.

The phenomenon of colour vision has been a point of controversy and a question of great debate in support of which a number of theories have been put forward by different physiologists in different times and none of them has been entirely successful due to unsatisfactory experimental verification.

General Theories of Colour Vision :

I. **Young-Helmholtz Hypothesis** : (a) *Single Cone Hypothesis*: A single cone is responsible for the perception of different types of primary colours. It cannot explain the causes of different types of colour blindness. (b) *Triple Cone Hypothesis* : Three types of cone receptors in the retina are responsible for perceiving three types of primary colours such as Red, Green and Blue. The macular part of the retina has got two types of cones which are responsible for Red and Green colour perception but the perception of Blue colour is responsible for the peripheral part of the retina.

II. **Hering's Theory** : This theory believes in the presence of three photochemical substances in the cones, one being responsible for one pair of complementary colours viz. one for red and green, another for blue and yellow and the third for black and white. During breakdown of the substance one colour sensation is produced. While during synthesis of the broken substance the complementary colour is produced.

Modern Concept of Colour Vision :

I. **Granit's Multiple Receptor Hypothesis or Polychromatic Theory** : *Granit* in 1945 studied the electro-physiological aspects of colour sensation and observe the discharges in single fibres of the isolated optic nerve in response to different wave lengths of light in dark-adapted and light-adapted frog's eye with the help of micro-electrodes.

Granit first completely isolated the different retinal receptors which he name them as "Modulators". Modulators are three groups of units—those affected by blue light (450—470mμ), those responding to green light (520—540mμ) and those affected by red-yellow light (580—600 mμ). Modulator receptors respond respectively to red-orange, to green and to blue. "Dominators" are responsible for different colour sensation such as seven types of spectral colours. The cones are the dominator receptors which are stimulated by the whole of the visual spectrum.

II. **Purkinje Phenomenon or Purkinje Shift** : *Purkinje* observed that the relative luminosities of hues changed as the luminance was reduced—the so called "Purkinje Shift". The maximum sensitivity is in the yellow colour sensation such as blue and thereby also shifted to the visibility curve.

III. **Dr. C. V. Raman's Recent Concept** : The refracting part of the light develops colour and is being acted upon the different cones. *Raman's* idea about colour vision are summarised as follows : (1) The photopic vision enable one to perceive both light and colour and scotopic only light but no colour. (2) The fading away of colour and of visual acuity in dimlight were both consequences of the corpuscular nature of radiation. (3) In bright light the yellow region of the spectrum is dominant. But in dim-light, both the red and the yellow sensations weaken and ultimately disappear, while the blue end of the spectrum is but weakly observable in dimlight. (4) The so-called visual purple present in the human retina is not actually a visual pigment but it only a physiological exudate which serves to keep the retina with its nervous structure in a state of health.

Q. 15. Describe the Colour Blindness.

The colour blindness means lack of appreciation of one or more colours.

Classification : The subjects with abnormal colour vision fall into several classes. 8·2% of the individuals show defect of colour vision. The conventional classification of colour blindness is suggested by *Von Kries*.

I. **Anomalous Trichromatism** : In this case, sub-normal preception of three primary colours such as red, green and blue are localised. The total amount of this type becomes 5·6%. This class is divided into three sub-classes : (a) *Protanomaly* or *Partial Protanopia*—Sub-normal preception of colour. It becomes 1%. (b) *Deuteranomaly* or *Partial Deuteropia*—Sub-normal perception of green colour. It becomes 4·6%, (c) *Tritanomaly* or *Partial Tritanopia* (0·0001%)—Sub-normal preception of blue colour.

II. **Dichromatism** : (2·6%). The complete loss of preception of individual primary colours are producing individual type of colour blindness. (a) *Protanopia* (1·2%)—Can not perceive red colour i.e., red colour blindness. (b) *Deuteranopia* (1·4%)—Can not perceive green colour i.e. green colour blindness. (c) *Tritanopia* (0·0001%)—Can not perceive blue colour i.e. blue colour blindness. It is found in detachment of retina, in jaundice, in heavy doses of santonin, etc.

III. **Monochromatism** (0·003%) : These are totally colour blind and see the whole spectrum is shades of grey. It is very rare and congenital and hereditary. They fall into two main groups according to their spectral sensivity and other characters. (a) *Red Monochromats* : These behave as if they possessed no cones. They may have a "central scotoma" or blind spot where the normal person has its fovea. Such subjects are rare. (b) *Cone Monochromats* : These are very rare and and apparently depend on cones. Rod vision (night vision) is apparently normal.

Tests For Colour Blindness : It is essential to those peoples who are drivers, signal man, seaman, air pilots, etc, because they have to distinguish between different colours. The following tests are generally done for colour blindness.

I. **Spectroscopic Test** : By this test, one can limits the visibility of spectrum, distinction between different spectral colours, their exact positions etc.

II. **Colour Matching Test** : (*Holmgren's Wool Test*) : It depends upon the inability of the colour blind to differentiate between certain pairs of coloured wools.

III. **Pseudo-isochromatic Test** : (1) *Ishihara Test* : It consists of a series of coloured plates each composed of a field of coloured dots. The dots are so selected and arranged as to consititute patterns visible either to the normal person or to the colour blind but seldom to both. (2) *Stilling Test.* (3) *100 Hue Test of Farnsworth.*

IV. **Coloured Light Test** : The *Edridge Green Lantern* in which the subject has to identify the colour of a small illuminated area the size of which can be varied.

Q. 16. What is meant by After Image ?

The persistance of vision even after the withdrawal of an objects is known as after image. After images may be of two types—Positive and Negative.

I. **Positive After Image** : It is an image of same kind of visual expression with same object and same colour. If the eyes are stimulated by a coloured light or a brightly coloured object or any sort and darkened an image of the same colour appears, these are called *Positive after image.* **Cause** : Persistence of physico-chemical changes of retina. **Experiments** : (1) A black Bidwell disc is moving on bright white opaque screen. Light projects from the slit and a Bid well's ghost appears. Due to the rotation of disc, the image formed on the screen, after removal, screen is illuminated. (2) The cinema picture is an example of positive after image and fusion of images and after images form the continuty of the picture.

II. **Negative After Image** : If instead of closing the eyes or turning them to a dark surface after looking at a white light, the retinas are stimulated second time and difusely by white i.e. one then sees the dark image against a white ground and this is called *Negative after image.* **Cause** : Retinal Inhibition.

Q. 17. What is meant by Contrast Phenomenon ?

The contrast phenomenon are of two types—Simultaneous contrast and Successive contrast.

(a) **Simultaneous Contrast** : When an object with a particular colour is viewed against a background of the complementary colour, both the colours appear to be more vivid which is produced due to negative after image. The red object appears vivid when put on the background of green colour, blue and black objects appear vivid when put on background of yellow and white colour respectively. **Cause** : It is due to negative after image. **Importance** : The simultaneous contrast is applied for the decoration of building or dresses of mankind.

(b) **Successive Contrast** : The eye is exposed to bright light and then the bright light is withdrawn. If the individual sees to the screen, it will look black. For instance, green light appears more vivid just after red light. **Cause** : It is due to negative after image.

Q. 18. What is dark Adaptation and Light Adaptation ?

The *Dark adaptation* is defined as the adaptation of the eye in room that is in dim light after prolonged exposure to bright light. It depends upon the resynthesis of visual purple which depends upon the vitamin A content in the body.

The *Light adaptation* is defined as the adaptation of the eye in bright light after prolonged exposure to darkroom.

Q. 19. What is Perimeter and Perimetry ?

The *Perimeter* is the record of the field of vision and *Perimetry* is the instrument by which the fields of vision can be recorded.

From the perimeter, it is found that temporal field of vision is greater than nasal field of vision. If the temporal field of vision is lost, it is concluded that nasal fibres in the optic nerve are destroyed. Similarly, if the nasal fields of vision are lost, there is destruction of temporal fibres in the optic nerve.

EAR (AUDITION)

Q. 20. Describe the anatomy of the ear and discuss their functions.

Ear is a special sense organ, situated inside the mastoid part of the temporal bone of the cranium and serves special functions known as hearing and maintenance of pose, posture and equilibrium.

Anatomy of the Ear : The ear has got three parts—External ear, Middle ear and Internal ear.

(a) **External Ear** : It has got two parts known as Pinna of Auricle and External auditory meatus. (1) **Pinna** or **Auricle** : It is a cartilagenous flattened expanded portion that acts as a receiver of sound and then conducts it through a narrow canal known as *external auditory meatus* to the *tympanic membrane.* The outer rim of the auricle is known as *helix*. In front of the helix, there is a curved hollow rim-like eminence known as *antihelix.* There is a deep depression in front of the antihelix, known as *concha.* From the lower end of the helix and antihelix, there is a non-cartilagenous structure hanging downwards which is known as the *lobule of the ear.* (2) **External auditory meatus** : It is a narrow cylindrical passage consisting of a cartilaginous and a bony part. It is directed downwards, forwards and medially. The skin of the external auditory meatus contains numerous seruminous glands which secrete the ear-wax.

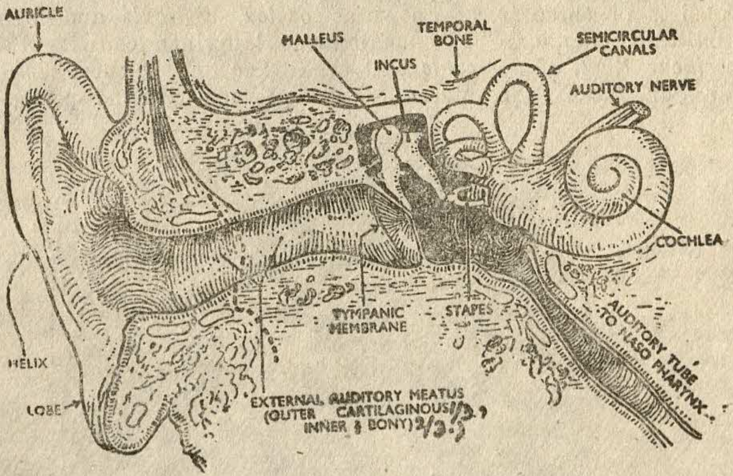


Fig. 47, Diagrammatic representation of the Ear showing the External ear, Middle ear and Internal ear.

(b) **Middle Ear or Tympanic Cavity** : In contains *atmos-*

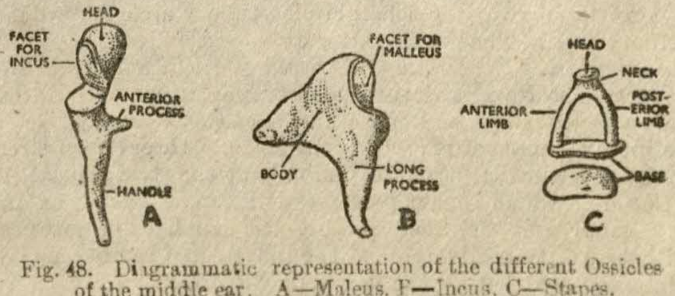


Fig. 48. Diagrammatic representation of the different Ossicles of the middle ear. A—Maleus. F—Incus. C—Stapes.

pheric air, *three auditory ossicles*, *tympanic membrane*, *tensor tympani* and *stapedius muscles* and *five ligaments*. In the middle ear, there are two windows known as *Oval window* or *Fenestra ovalis* and the *Round window* or *Fenestra Rotunda.* The three ossicles are known as *Maleus*, *Incus* and *Stapes.*

(c) **Internal Ear :** It consists of a outer bony labyrinth consists of three parts known as *cochlea*, *vestibule* and *three semi-circular canals.* The membranous labyrinth consists of a *cochlear duct*, the *saccule* and the *utricle* and the three *semi-circular ducts.* The internal ear is concerned with the perception of sound and maintenace of equilibrium. (1) **Cochlea :** It consists of two and a half circled tube which looks like the shell of a snail. The cochlea after cross-section, consists of three canals known as *Scala tympani*, *Scala vestibuli* and *Scala media* or *Ductus cochlearis* and three membranes known as *Vestibular membrane*, *Basilar membrane* and *Reissner's membrane.* (2) **Vestibular apparatus :** It consists of three semi-circular canals. Each canal possesses ampulla at the two ends. After section, it is found that it possesses two canals known as outer bony canal and the inner membranous canal. The outer canal is filled up with perilymph and the inner canal is filled up with endolymph that bathes the hair cells within it.

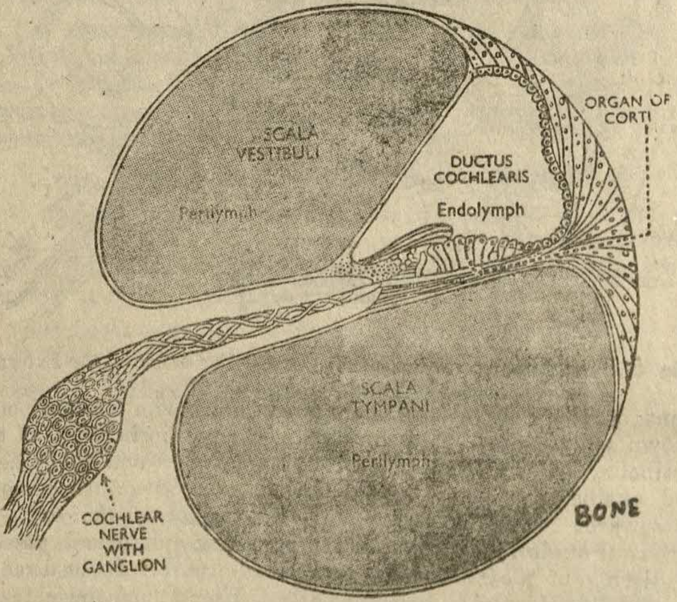


Fig. 49. Schematic representation of the Cochlea showing its different canals and organ of corti.

Functions of the Ear : (1) The external ear helps in the reception of sound for its shape and mobility. (2) The middle ear helps in ossicular conduction due to the presence of ossicles. (3) The cochlea serves path and mechanism of hearing. (4) The vestibular apparrtus maintains pose, posture and equilibrium. (5) The perilymph and endolymph of the internal ear serves the transmission of sound waves when basilar membrane is vibrated.

Q. 21. Describe the structure of Organ of Corti and discuss the Path of Hearing.

Ear is a special sense organ, situated in the special part of the cranium i.e., over and inside the mastoid part of the temporal bone, performing special types of functions by the internal ear. The cochlear part is responsible for hearing and the vestibular part is responsible for maintenance of pose, posture and equilibrium.

Structure of Organ of Corti : The organ of corti is situated within the duct of cochlea. The auditory receptors are present in the organ of corti. The organ of corti is placed on the basliar membrane, where two types of *fibres* or *stings* can be found and the fibres are : (1) Short fibres, which will vibrate by the sound of high tone. (2) Long fibres, which will vibrate by the sound of low tones. There are two types of *hair cells* which are : (1) The inner hair cells are arranged in a single row and provided with hairs. (2) The outer hair cells are arranged in three rows and also provided with hairs. There is also outer rod of corti and inner rod of corti. The convex head of the outer rod of corti fits into the concave head of the inner rod of corti. The two rods of corti meet at the base to form a tunnel, known as *Tunnel of Corti.* The outer hair cells are supported by two types of *supporting cells.* (1) Inner supporting cells known as *Dieter's cells* which are situated in between the hair cells. (2) *Cells of Hensen* which are situated on the outer aspect of the hair cells. On the extreme outer aspect of the basilar membrane, there are cubical cells known as *Cells of Claudius.* The organ of corti is supported by *Membrana Tectoria* which extends upto the outer hair cells.

Path of Hearing : The path of audition concerns about the sensory and reflex path of hearing.

I. **Sensory Path** : The sensory path of audition starts from organ of Corti and forms auditory tract via spiral ganglia. The auditory tract enters into the pons and relay to the dorsal and ventral cochlear nuclei from there, next neurone arises and form a bundle and called *lateral fillet* or *lateral leminiscus* in the mid-brain and end in the *Medial geniculate body* and *Inferior colliculus.* The medial geniculate body is responsible for auditory sensation. The fresh order of fibres take origin from medial geniculate body, form *auditory radiation*,

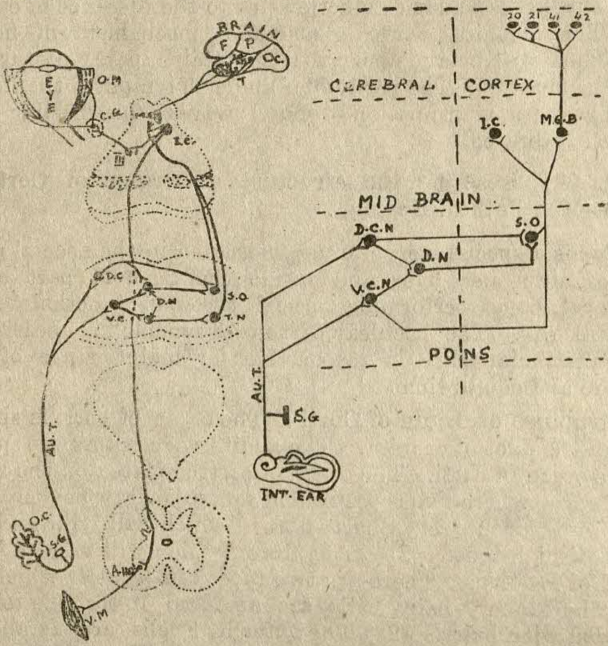


Fig. 50. Path of Hearing with diagrammatic representation of Auditory Analyser (Left side).

O.M.—Ocular Muscle, C.G.—Ciliary ganglia, M.G.—Medial Geniculate body. I.C.—Inferior Collicular Structure, III—Cranial Nerve Nuclei, D.C.N.—Dorsal Cochlear Nerve Nuclei, V.C.N.—Ventral Cochlear Nerve Nuclei, S.O.—Superior Olive, T.N.—Trapezoid Nuclei, A.U.T.—Auditory Tract, S.G.—Scarpus Ganglia O.C.—Organ of Corti, A.H.C.—Anterior Horn Cell, V.M.—Voluntary Muscle, 20, 21, 41, 42—Auditory Areas of Temporal Cortex.

pass through posterior limb of internal capsule and end in audito-sensory area (Superior temporal gyrus and Heschl's gyrus), audito-psychic and audito-motor area of the temporal lobe of the cerebral cortex.

II. **Reflex Path** : The reflex path of hearing concerns about Body Reflex and Eye reflex. The inferior colliculus is responsible for starting of auditory reflexes. (a) **Body Reflex :** This reflex is done by *Tecto-spinal tract reflex*. The fibres originate from inferior colliculus, cross to the opposite side and pass through mid-brain, pons, medulla and relay to the anterior horn cell of of the spinal cord. From there, another set of fibres arise and relay to the voluntary muscles. (b) **Eye Reflex :** The fibres arise from inferior colliculus, cross to the opposite side and relay in the third nerve nuclei. From there, another sets of fibres arise and relay in the ciliary ganglia. From this ganglia, short ciliary nerve arises and relay to the ocular muscles.

Q. 22. Describe the Theories of Hearing.

Ear, the auditory analyser, is composed of a composite set of nervovs mechanism. The mechanism of the internal ear has been for many years a subject of lively contoversy to which both physiologists and physicists have contributed. The appreciation of pitch has been the pivot around which discussions of cochlear functions have turned and the several theories which have been proposed are attempts to explain the extraordinary faculty of the auditory mechanism.

Classification of the Theories of Hearing : The theories concerning hearing are mainly of two categories : (1) Theories which are concerned with the fact that the true sound analyser is the cochlea of the internal ear, viz. The Resonance Theory, The Place Theory etc. (2) Theories which are based on the fact that the analysis of sound occurs in the brain but not in cochlea, viz. Telephone Theory.

Different Theories of Hearing :

I. Helmholtz's Resonance Theory : In this theory, *Helmholtz* compares the organ of corti and basilar membrane with the resonator. *Helmholtz* states that the organ of corti and the basilar membrane together act as a series of automatically recording resonator. The resonance theory postulates that the analaysis of sound into its constituent frequencies is primarily a function of cochlea. (1) *Helmholtz* first believed that organ of corti is the seat of vibrations for producing auditory impulses but later it is proved that basilar membrane act as vibrators. (2) The short lower fibres of cochlea respond to high-picted tones but the long upper fibres respond to low pitched tones.

II. Rutherford's Telephone Theory : In this theory, *Rutherford* compares the organ of corti with the telephone. According to this theory, cochlea possesses no faculty of sound analysis. The frequency of impulse transmitted over each fibre of the auditory nerve bring the sole basis for the estimation of pitch. The intensity of sound is therefore a function of the number of active nerve fibre. The cochlea on the other hand acts as a telephone. The vibration of the basilar membrane as a whole, like the diaphragm of the telephone, causes impulses to be sent up by the auditory nerve which corresponds with the air vibration received by the ear. Therefore the true analysis of the sound takes place in the brain.

III. **Helmholtz's Place Theory** : In this theory, *Helmholtz* gives discussion about the different positions of hair cells of the organ of corti over the basilar membrane. The place theory of pitch discrimination is firmly established to-day on the basis of interpretation of acoustic phenomenon. According to this, the hair cells will respond more easily to one frequency than another, those at the apex, responding preferentially to low tones while those at the base of the cochlea responding to high tones.

IV. **Wever's Resonance-Volley Theory** : *Wever* in 1949, has shown that two theories such as *Resonance* and *Telepeone Theory*, can be combined in his *Resonance-Volley theory*, which uses the telephone or volley principle to explain the response of the whole cochlea to low frequencies and the place or resonance priciple to explain the cochlear analysis of higher frequencies.

V. **Georg Von Bekesy's Travelling Waves Theory**. In this theory, *Von Bekesy* shows the formation of travelling waves on the basilar membrane. By increasing the stiffness of the basilar membrane, the whole membrane would vibrate in phase giving the response. By decreasing the stiffness of the membrane, but increasing the lateral adhesions of its component fibres, a steady tone may cause a travelling wave but runs rapidly along the membrane but dies at a certain point. If the frequency becomes gradually lowered, a tone is reached when all parts of the organ of corti are stimulated.

VI. **Von Bekesy's Standing Waves Theory** : On decreasing the stiffness of the membrane still further, the tone produces travelling waves, but these travel so rapidly that they are reflected from the end of the membrane to produce standing waves. The membrane is deflected at a number of nodes and the positions of these nodes depend on the frequency of the stimulating note.

VII. **Pattern Theory** : *Caldwell*, *Glaesser* and *Stewart* in 1962, hold that the patterns are envoloped of transverse quasi-sinusoidal vibrations along the cochlear duct, each pattern corresponding to a different sustained sound, temporal, sequences of patterns would represent phonemes.

Q. 23. Describe the Mechanism of Hearing.

The mechanism of hearing is done by the different anatomical structures of the ear and the conversion of air sound into vibrations of a membrane—the basilar membrane in a fluid filled cavity—the inner ear.

I. **Contributions of External Ear and Tympanic Membrane** : The sound waves are first received by the pinna and then the wave will pass through the external auditory meatus and will fall on tympanic membrane. The sound waves will cause the vibration of tympanic membrane, which is a periodic, i.e. it vibrates only when the sound waves impringe on it. The different parts of external ear contributes in the mechanism of hearing which are :

(a) **Shape of the Auricle** : It might serve as a concave reflector to concentrate sound vibrations and direct them into the external auditory meatus.

(b) **External auditory Meatus** : It looks like a vertical 'S'-shaped tube only to maintain the increased velocity of sound production due to its peculiar pattern.

(c) **Tympanic Membrane** : It does not faithfully reproduce the from of the incident sound waves, but modifies them, the new vibratory motion being then transmitted through the ossicles to the internal ear.

II. Contributions of the Middle Ear :

(a) **Three Ossicles** : The vibration of the tympanic membrane will then pass through the handle of malleus, then to the head of the malleus, then to the head of the incus, then to the long process of the incus, then to the head of the stapes and through the two crura of stapes. It will ultimately reach the base of of the stapes from where the sound waves will enter into the internal ear passing through the oval window.

(b) **Tensor Tympani and Stapedius** : The ossicles are held together by articular ligments and the whole system is suspended by eight other ligaments, two of which lead to muscles —the tensor tympani and the stapedius.

III. Contributions of the Internal Ear : There are three chambers in the cochlea known as Scala vestibuli, Scala media and Scala tympani. The scala vestibuli and scala tympani connect by way of the helicotreme, they contain perilymph which is continuous with that in the vestibular apparatus by way of the vestibule, the scala media or cohlear duct, contains endolymph.

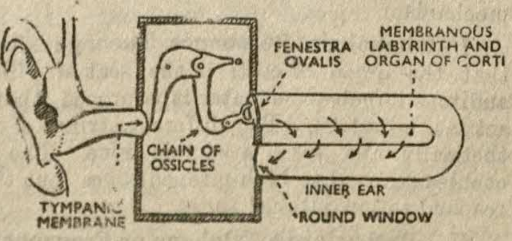


Fig. 51. Diagrammatic representation of the different parts of the ear showing the path of viabrations from external ear to the internal ear through the ossicles.

(a) **Transmission of Sound Waves** : The ear drum and the ossicles act as a kind of transformer to convey vibrations of the light medium, air, to the dense medium, water, in the internal ear. The air bone sounds pass into the three ossicles, oval window and will enter into the perilymph of scala vestibuli.

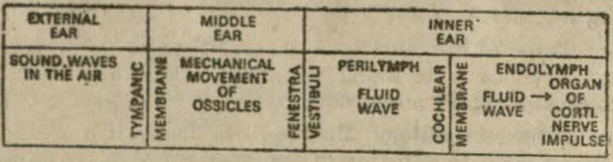


Fig. 52. Illustration showing the conduction of sound waves through different parts of the ear.

The vibration strikes upon the Reissner's membrane, passes through scala media and will vibrate the Basilar membrane. From this membrane, the sound waves pass through scala tympani and will enter into the round window.

(b) **Stimulation of the Hair Cells** : The vibration of the basilar membrane will vibrate the hair of the inner and outer hair cells which are the receptors of hearing. In the hair cells, sound waves will be converted into nervous impulses which will pass through the cochlear division of the 8th nerve and will reach the bipolar cells of the spiral ganglion.

Q 24. Describe the Theories of Perception of Pitch.

The mechanism of the internal ear has been for many years a subject of lively controversy to which both physiologists and physicists have contributed. The appreciation of pitch has been the pivot around which discussions of cochlear functions have turned and the several theories which have been proposed are attempts to explain the extraordinary faculty of the auditory mechanism.

I. Helmholtz's Resonance Theory : *Helmholtz* first believed that the organ of corti is the seat of vibrations for producing auditory impulses but later it is proved that basilar membrane act as vibrators. The different strings of piano vibrate sympathetically and form a simple tone. The short lower fibres of cochlea respond to high-pitched tones but the long upper fibres respond to low-pitched tones.

II. Rutherford's Telphone or Frequency Theory : *Rutherford* in 1886, established his own theory and suggests that the true analysis of the sound takes place in the brain. Here the cochlea acts as a telephone. The vibration of the basilar membrane as a whole, like diaphargm of the telephone, causes impulses to be sent up by the auditory nerve which corresponds with the air vibration received by the ear.

III. **"Place Theory" of Helmholtz** : The place theory of pitch discrimination is firmly established to-day on the basis of interpretation of . acoustic phenomenon. According to this, the hair cells at the apex of the basilar membrane responding preferentially to low tones, whilst those at the base of the cochlea responding to high tones.

IV. **Bekesy's Travelling Wave Theory** : By decreasing the stiffness of membrane, but increasing the lateral adhesion of its component fibres. a steady tone may cause a travelling wave that stimulates all parts of the organ of corti.

V. **Bekesy's Standing Wave Theory** : The standing waves are produced due to rapid travelling wave formation from the end of the basilar membrane which stimulate the hair cells of the organ of corti.

Q. 25. Describe the Structure of Otolith organ and functions of Vestibular apparatus.

The hairs of utricle and saccule are supported by calcareous materials known as *Otoliths* and hence utricle and saccule together called *Otolith organs*. When head moves in any direction in relation of the trunk, there will be movement of the endolymph which will produce vibration of the hairs in crista to initiate the nerve impulses which will pass through vestibular division of the eighth nerve.

Structure of Otolith Organ : The otolith organ consists of utricle and saccule.

(a) **Utricle** : It has got an outer bony covering and an inner membranous covering. The perilymph is present in between the bone and membrane and endolymph is present within the membranous canal. The utricle at one end communicates with the semicircular canal and at other end communicates with the saccule by ductus endolymphaticus. There is a swelling known as "*macula*" which contains the receptor known as "*Crista*".

(b) **Saccule** : It has got outer bony covering and inner membranous covering. The perilymph is present in between the bone and the membrane. The endolymph is present within the membranous canal. The saccule at one end communicates with the utricle by ductus endolymphaticus and at the outer end communicates with the cochlea by the duct of cochlea or "*Duct of Rennius*". There is a swelling in the saccule known as '*macula*' which contains the receptors known as '*Crista*'.

(c) **Crista** : This crista is of tall columnar epithellial cells provided with hairs. The hairs are supported by a dome shaped structure known as '*Cupula*'.

Functions of the Vestibular Apparatus : The following are the functions of the vestibular apparatus: (1) The vestibular division of the 8th nerve carrying the impulses from the receptors of the vestibular apparatus, will relay in the vestibular nuclei in the pons. (2) The fibres from the lateral vestibular nucleus will relay in the flocculo-nodular lobe of the cerebellum passing through inferior cerebellar peduncle as vestibulo-cerebellar tract. (3) The flocculo-nodular lobe will send efferent fibres to the lateral vestibular nucleus known as cerebello-vestibular tract. (4) The destruction of the lateral vestibular nucleus or sections of the vestibulo-spinal tract produces flaccidity of the muscles due to the complete loss of the tone of the muscles. (5) The fibres from the superior vestibular nucleus will ascend upwards through posterior longitudinal bundle and control the different movements of the eye ball in different directions. (6) From the inferior vestibular nucleus, the fibres will relay in the red nucleus of the opposite side as cerebello-rubral tract.

Q. 26. Describe the structure of Semi-circular Canals and discuss the importance of Vestibular apparatus (Semi-circular Canals) in the maintenance of posture and equilibrium.

The higher animals normally exhibits characteristic attitudes in response or action, by which they are oriented with reference to gravity. To any circumstance which tends to displace the animal from its posture there is offered a resistance which prevents the displacement or which tends to restore to animal to its correct attitudes.

Structure of the Semi-Circular Canals : There are three semicircular canals known as *lateral*, *anterior* and *posterior*. The lateral canal is horizontal and the other two are vertical in position. Each canal begins in a dilatation called the *ampulla*. The specific vestibular sense organs known as *crista ampullaris* are present within each ampulla. It has got two converings—outer bony and inner membranous. The outer bony canal is filled up with perilymph and inner membranous canal is filled up with endolymph within which the hair cell or vestibular end organs are lodged.

Each canal has got three layers known as outer coat, middle coat and inner coat. The ampulla contains *crista ampullaris* which consists of a ridge of *neuro-epithelium* surruonded by *planum semilunatum*. The neuropithelium comprises two types of hair cells known as Flask-shaped cell (*Type I of Wersall*) and Cylindrical cell (*Type II of Wersall*). Between the hair cells, *supporting cells of Retzius* lie.

Structure of Utricle and Saccule : The utricle and saccule each contain within their walls, areas of sensory neuro-epithelium called the macula utriculi and macula sacculi. Their epithelium contains two types of cells known as *Sustentacular* or *Supporting cells* and *Hair cells*. Over the surface of the maculae there is a gelatinous layer, the *Otolithic membrane*, into which the hairs of the hair cells penetrate. In the upper portion of the "jelly" are found many minute crystalline bodies called *Otoliths* or *Otoconia*, which are made up of calcium carbonate and a protein.

Path of Pose and Postural Impulses : This path comprises of postural sensation and postural reflexes.

I. **Postural Sensations** : The fibres arising from the hair cells of the semi-circular canal from scarpas ganglia and vestibular tract which relay to the Dieter's nuclei of the pons. From there, second neurone arises, passes through crus, substantia nigra, tegmentum of the mid-brain and relay to the nuclei of the Reticular formation and Red nucleus. These two nuclei also receive vestibular impulses, visual impulses, impulses from the muscles of neck, trunk and limbs and skin impulses through Goll and Burdach tract.

II. **Postural Reflexes** : The postural reactions of the body when at rest and the body is not in locomotion, are called "Static Reflexes" and the postural reactions of the body when in movement are called "Stato-kinetic Reflexes".

(A) **Static Reflexes** : (a) Local static reactions e.g. confined to one limb. (b) Segmental static reactions, involving one segment e.g. both hind limbs, both forelimbs or the neck. (c) General static reactions involving more than one segment and are divided as :

(1) *Reflex Stance* : (i) Influence of the head on stance—Effect of tonic neck reflexes on forelimbs, effect of tonic labyrinth reflexes, collaboration of neck and labyrinth reflexes, indirect influence of labyrinth on limbs through action on neck reflexes. (ii) Indirect influence on posture.

(2) *Compensatory Pose of Eyes* : (i) Effect of tonic labyrinth reflexes on eyes. (ii) Effect of tonic reflexes on eyes. (iii) Collaboration of tonic labyrinth and neck reflexes on eyes. (iv) Collaboration of compensatory eye pose.

(3) *Righting Reflexes* : (i) Effect of labyrinth reflexes on the head. (ii) Effect of body posture on the head. (iii) Neck postural reflexes. (iv) Effect of body postural reflexes on the body itself. (v) Visual postural reflexes.

(B) **Stato-kinetic Reflexes** : (When the body is in locomotion.)

(a) *Reactions to Rotation* : (1) Head reactions. (2) Eye reactions.

(b) *Reactions to Progressive movement*: (1) Reactions of head. (2) Reactions of extremities.

Q. 27. What is Righting Reflexes ? Discuss briefly.

The reactions by which an animal keeps itself right side up and recovers its normal posture after it has been disturbed, are well illustrated in the familiar example of the falling cat, which always lands on its feet. When such an animal be laid on its side, the head atonce rights itself followed by the body, gradually assuming the upright position and this type of reflex is called *righting reflex*.

Types of Righting Reflexes: The Righting reflexes are present at birth and are carried out by co-operation of five different groups of reflexes.

I. **Labyrinthine Righting Reflexes and Head pose**: When the animal's head on one side, impulses arise in the saccules which lead reflexly to righting of the head in its normal position in space.

II. **Body Righting Reflexes on the Head**: With the animal on its side, the side of the trunk in contact with the bench is undergoing constant stimulation while the other side in contact with the air is not. In such case, righting of the head occurs due to a symmetrical stimulation.

III. **Neck Righting Reflexes acting upon the Body**: These reflexes act primarily on the neck muscles and correct the head in position. When the animal is placed in one side of it in the table, impulse arises from the saccules and thus the head is raised. The neck righting reflex evokes a further reaction which brings the thorax and lumbar region successively in the upright position.

IV. **Body Righting Reflexes acting upon the Body**: When the thalamic animal is said upon its side but the head held down to the table so as to eliminate the righting reflexes of labyrinthine and cervical origin, as well as the body righting reflex acting upon the head, the body never the less right itself.

V. **Optical Righting Reflexes**: In animals with calcarine cortex intact, righting of the head is also brought about reflexly by means of optical impulses. The centre for this reflex is the occipital cortex, when impulses pass to the neck muscles to right the head.

TASTE (GUSTATION)

Q. 28. Describe the structure of Taste buds and path of Taste Impulses.

The tongue is a muscular organ, situated partly in the mouth and party in the pharynx generally associated with the functions of speech and deglution but specially the functions of taste. It is a selector of food, director of mastication, helper in the formation of bolus and deglutition, possesser of taste buds, discriminator of different zonal taste sensibility, carrier of taste sensations to the uncus and hippocampal zone of allocortex and a great orator of human being.

Lingual Papillae : The mucous membrane of the tongue shows certain projection of the corium which are of different types : (1) *Filiform Papillae* : They are found on the anterior 2/3rd of the dorsal surface of the tongue. They are minute conical structures which do not contain taste buds.

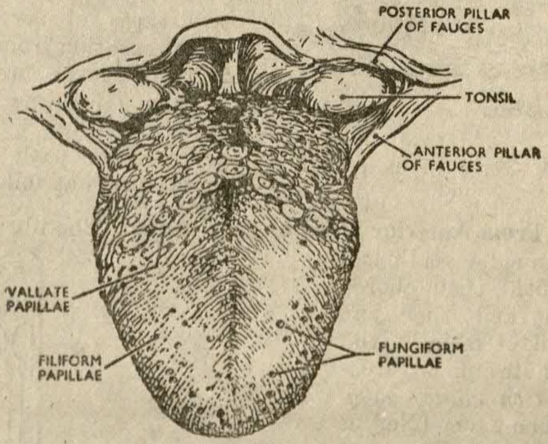


Fig. 53. Structure of Tongue showing its different papillae.

(2) *Fungiform Papillae* : They are situated at the tip and edges of the tongue. They are larger and round in shape. (3) *Circumvallate Papillae* : They are found at the junction of anterior 2/3rd and prsterior 1/3rd of the tongue and are situated in the mucosa forming the walls of this circular trench. Each papilla is a central rounded elevation, 6 to 12 in number.

Structure of Taste Buds : The taste buds are oval bodies and lies with its long axis perpendicular to the epithelial surface. (The taste bud consists of two types of cells : (a) **Gustatory Cells** : They occupy the central portion of the taste bud and consist of : (1) *Fusiform Cells* : These are known as taste cells which are spindle shaped and a large spherical nucleus near its centre. (2) *Taste Hairs* : These are hair like processes, present in gustatory pore or taste pore. (b) **Susten-ticular Cells** : These are supporting cells without hair. They consist of *Peripheral supporting cell* and *Central supporting cell*. The central supporting cells are present in between the bipolar cells and peripheral supporting cells which are arranged like the peals of one on the other.

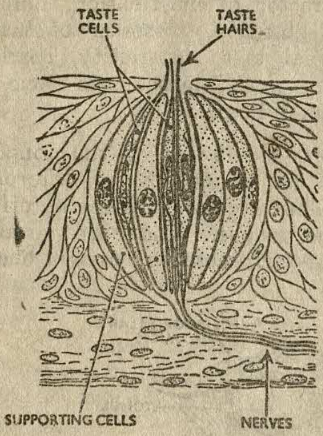


Fig. 54. Structure of a Taste bud.

Path of Taste Impulses : The sensation of taste by the tongue is carried by the two types of nerves. The taste sensation from anterior 2/3rd of tongue are carried by the 7th nerve and from posterior 1/3rd by the 9th nerve. The path of taste sensations is as follows :

(a) **From Anterior 2/3rd of the Tongue** : The fibres of taste sensation enter via lingual nerve (5th), then chorda tympani and then join the trunk of facial (7th). The cell station is situated in *Geniculate ganglion*. The axons (Nervus intermedius of Wristers) of these cells enter and end in the dorsal sensòry nucleus (Nucleus Tractus) of the facial nerve where first neurone ends. The second neurone arises, crosses to the midline, passes through the medial fillet and end in opposite side of the lateral nucleus of the Thalamus. The third neurone arises, passes through the posterior limb of the internal capsule and end in the hippocampal region of the allocortex of the cerebrum.

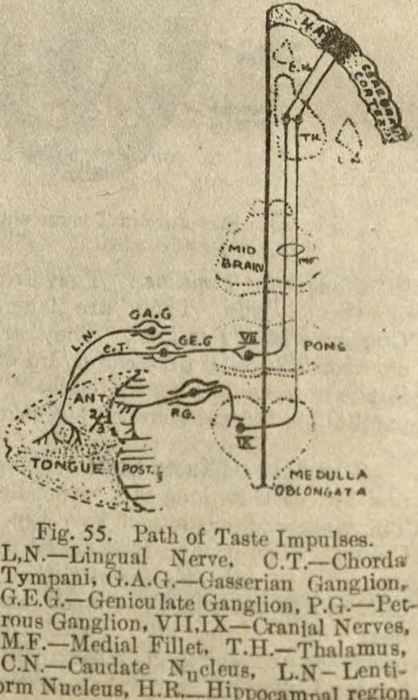


Fig. 55. Path of Taste Impulses. L,N.—Lingual Nerve. C.T.—Chorda Tympani, G.A.G.—Gasserian Ganglion, G.E.G.—Geniculate Ganglion, P.G.—Petrous Ganglion, VII,IX—Cranial Nerves, M.F.—Medial Fillet, T.H.—Thalamus, C.N.—Caudate Nucleus, L.N—Lentiform Nucleus, H.R.—Hippocampal region.

(b) **From the Posterior 1/3rd of the Tongue**: The fibres of taste sensation arises, pass along glossopharyngeal nerve enter their cell station in *Petrous ganglion* and end in dorsal sensory nucleus of the glossopharyngeal nerve (9th) where first neurone ends. The second neurone arises, crosses to the mid line, passes through the medial fillet and end in the opposite side of the lateral nucleus of the Thalamus. The third neurone arises, passes through the posterior limb of the internal capsule and end in the hippocampal region of the allocortex of the cerebrum.

SMELL (OLFACTION)

Q. 29. Describe the structure of Olfactory epithelium and path of Olfactory Impulses.

The nose is an organ of smell. The olfactory epithelium possesses olfactory nerve cells which are responsible for smell sensations.

Structure of Olfactory Epithelium: The whole nasal mucous membrane is not sensitive to smell. The small olfactory area is yellow in colour and occupies part of superior concha, roof of nose and upper part of nasal septum. The olfactory area is composed of there types of cells: (a) **Supporting Cells**: These are very high columnar type with large oval nuclei. They are conical in pattern with yellow pigment granules. (b) **Basal Cells**: They give origin of supporting cells. They are short and columnar in type. (c) **Bipolar Olfactory Nerve Cells**: They are essential olfactory sense organ. Each cell possesses fusiform cell body and two processes arise from the opposite poles of the cell body.

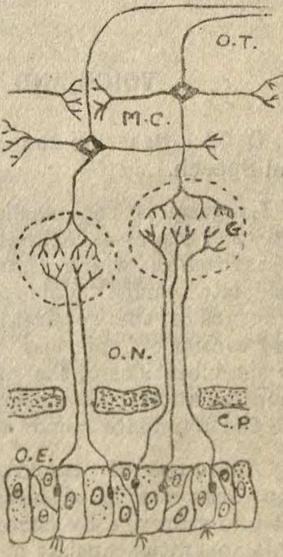


Fig. 56. Path of Olfactory Impulses.
O.E.—Olfactory Epithelium. C.P.—Cribiform plate of Ethmoid bone. O.N.—Olfactory Nerve. G—Olfactory Glomeruli. M C.—Mitral Cell. O. T.—Olfactory Tract.

Path of Olfactory Sensations: The axons of the olfactory nerve cells form *olfactory nerves.* They ascend upwards through perforations of the cribiform plate of the ethmoid bone. The olfactory nerves enter the *olfactory bulb*, in which several cells are present—some are *mitral cells* and some are *tufted cells*. The dendrons of the mitral and tufted cells make a synaptic function with the axon of bipolar cells and form *olfactory glomeruli* where first neurone ends. The axons of mitral and tufted cells come out of olfactory bulb and form *olfactory tract*. This olfactory tract ends in the *olfactory pyramid* where second neurone ends. The olfactory pyramid divides into lateral and medial roots. (a) **Lateral Root**: It passes through anterior perforated substance and ends in *uncus*. From there it will go into the *alveus* which is a layer of white fibres lying on ventricular surface of *Pes Hippocampus* that is the anterior part of the hippocampus where third neurone ends. (b) **Medial Root**: It passes through paraterminal gyrus, indusium gresium, splenial gyrus, dentate gyrus, uncus and alveus where third neurone ends. The 4th order of fibres take origin from *fimbria* and end as the posterior column of *Fronix*.

VOICE AND SPEECH (PHONATION)

Q. 30. Describe the mechanism of production of Voice and Speech.

Language is the mechanism by which man communicates ideas and expresses feelings ; speech is a highly developed form of language in which thoughts and feelings are expressed by articulate sounds. Voice is the purposive production of sound by means of the respiratory organs. Paradoxically, the voice may consist of "voiceless" sounds or "voiced" sounds produced by the vibrations of the vocal folds. Of all the stimuli acting upon the auditory analyser of man, some of the most important are the articulate sounds which constitute speech.

Anatomy of the Vocal Apparatus: The human vocal apparatus consists of the larynx with its vocal cords which are set into vibration by currents of air emitted from the lungs. This apparatus consists of : (1) The skeleton of the larynx is formed by a number of cartilages known as thyroid cartilage and the two arytenoid cartilages. (2) The epiglottis situated infront of the upper opening of the larynx is a value which closes the entrance to the larynx and prevents food and saliva from getting into it. (3) The true vocal cords i.e.. ligamentum vocalia vera are two symmetrically situated folds of the mucous membrane of the larynx containing elastic fibres. (4)

The medial free margins of both vocal cords protrude into the larynx as pointed edges which form *rima glottidis*. (5) Between the true and false vocal cords, on the lateral wall of the larynx there is a pocket-shaped recess known as laryngeal ventricle which in some animals is a highly *resounding cavity*.

Mechanism of Production of Voice : Voice is produced in the larynx, a modified portion of the wind-pipe, by the vibrations of two elastic bands, the vocal cords, which are set into action by the expiratory current of air from the lungs. In the larynx, the note is produced by the blast of air which is modified partly by alterations in the tension of the vocal cords, partly by alterning the size of the aperture and partly by varying the strength of the blast of air.

Mechanism of Production of Speech : Speech is a specific human function which developed in the process of collective labour as a means of intercourse, it is indissolubly connected with the development of abstract thinking. Speech is composed of "Vowels" and "Consonants". The vowels are tonal sounds, while the consonants are predominantly noise sounds. The Vowels are formed by the compound sound, produced by the vibrations of the vocal cords contains a large number of overtones. The Consonants play a role of noise sounds arises in the cavities of the pharynx, mouth and the nose.

Q. 31. Write Short Notes On :

(a) **Retina** : It is a photosensitive organ situated in the innermost layer of the eyeball. *Structure* : It has a complex structure which is sensitive to light and contains nerve cells and supporting structures. The retina consists of ten layers—one is pigment layer, two are limiting membranes and the rest seven layers are nervous in structure. The layers of the retina are : (1) Pigment cell layer. (2) Layers of Rods and Cones. (3) External limiting membrane. (4) Outer nuclear layer. (5) Outer plexiform layer. (6) Inner nuclear layer. (7) Inner plexiform layer. (8) Ganglion cell layer. (9) Stratum optium or Optic nerve fibre layer. (10) Internal limiting membrane. *Functions* : The functions of retina are : (1) The rods are responsible for dimlight vision and peripheral vision. (2) The cones are responsible for bright light vision, colour vision and acquity of vision. (3) The macula lutea is responsible for dimlight and bright light vision.

(b) **Light Reflex** : It is a reflex which occurs when light falls on the retina and pupil contracts even to a pin point of the same side. This reflex is determined by the contraction of sphincter pupillae together with a relaxation of the dilator muscle. *Path* : The path of light reflex consists of afferent fibres, centre and efferent fibres. (1) The *afferent fibre* originates from the optic tract after forming optic chiasma and relay in the pre-tectal nucleus and then to the 3rd cranial nerve nuclei which are situated in the tegmentum part of the mid-brain. (2) The *centre* of light reflex is the Edinger Westphal nucleus of the 3rd nerve of the opposite side. (3) The *efferent fibre* originates from the 3rd nerve nucleus and forms ciliary ganglia. From there, short ciliary nerve arises which relay to the sphincter pupillae of the iris. *Importance* : It is of great advantage in case of children as it determines objectively whether the eye has any sensation of light or not. **Value** : The light reflex is a very valuable sign of the presence of perception of light.

(c) **Middle Ear** : It is the middle part of the ear which lies in between the bottom of the external auditory meatus and the internal ear of the labyrinth. *Contents* : (1) Tympanic membrane. (2) Bony ossicles comprising malleus, incus and stapes. (3) Ligaments. (4) Muscles. (5) Atmospheric air. *Functions* : It conducts the vibrating sound to the internal ear via bony ossicles.

(d) **Myopia** : The patient can see the near objects but cannot see the distant objects. *Description* : In this type of refractive error, the eye ball is too long, relatively to its refracting power and the eye will bring the parallel rays to a focus infront of the retina. *Cause* : This defect is due to : (i) Abnormal elongation of the eye ball. (ii) Increased convexity of the cornea. (iii) More accumulation of aqueous humour. (iv) Abnormal elongation of the lens on its anterior aspect. (v) Disturbed electrolyte metabolism in diabetes produces osmotic changes in the lens producing myopia. *Correction* : A myopic or short sighted eye can be corrected by the use of concave glasses which diverge the rays entering the eye.

(e) **Hypermetropia** : In this type of defect, the patient can see the distant objects but cannot see the near objects. This type of defect if found in young subjects. *Description* : In this condition, the eye is too short in its antero-posterior diameter for its refracting power and the parallel rays from near objects will fall behind the retina. The near point in this cases is further away than in the normal eye. *Cause* : This defect is due to : (i) Diminished convexity of the cornea. (ii) Narrowing of the lens in its antero-posterior diameter. (iii) Less formation of aqueous humour. *Correction* : A hypermetropic or long-sighted eye can be corrected by the use of convex glasses which converge the rays entering the eye.

(f) **Auditory Ossicles** : There are three bony ossicles such as malleus, incus and stapes. (1) *Malleus* : It has got head, lateral process and handle. The head of the malleus articulates with the body of incus. The handle of malleus is present in between the mucous membrane and the fibrous coat. (2) *Incus* : It has got body, short process and long process which articulates with the body of the stapes. (3) *Stapes* : It has got head, constricted neck, two crura and base of the stapes. The base of the stapes fits itself into the oval window to transmit the sound waves from the middle ear to the internal ear.

(g) **Organ of Corti** : It is the end organ of audition. *Situation* : The organ of corti is situated within the duct of cochlea or scala media. It is placed on the basilar membrane. *Structures* : The organ of corti possess two types of fibres which are : (i) Short fibres or stings will vibrate by the sound of high tone. (ii) Long fibres will vibrate by the sound of low tones. There are two types of hair cells in the organ of corti which are : (i) The inner hair cells are arranged in a single row and provided with hairs. (ii) The outer hair cells are arranged in three rows and also provided with hairs. There are outer rod of corti and inner rod of corti. The two rods of corti meet at the base to form a tunnel known as Tunnel of corti. The outer hair cells are supported by two types of supporting cells which are : (i) Inner supporting cells known as Dieter's cells. (ii) Cells are Hensen are situated on the outer aspect of the hair cells.

There are cubical cells known as cells of Cludius which are situated on the extreme outer aspect of the basilar membrane. The organ of corti is supported by Membrana tectoria that extends upto the outer hair cells.

(h) **Basilar Membrane** : It is a partitioning membrane that separates Scala tympani from Scala media. *Structures* : The basilar membrane is narrower at the base but broader at the apex. It consists of parallel fibres in a gelatinous sheet. *Functions* : The basilar membrane acts as a resonator which vibrates the organ of corti that will help in the transmission of auditory impuleses.

(i) **Circumvallate Papillae** : These are minute projections of the mucous membrane over the tongue surface. *Situation* : They are situated at the back of the tongue and arranged in the form of a V with its limbs opening anteriorly. *Structures* : This papilla consists of a central-rounded elavation, surrounded by the non-cornified stratified squamous epithelium on the lamina propria. The mucous membrane is raised externally to this groove which is known as vallum. *Function* : These papillae serve the function of bitter taste sensations.

(j) **Taste bud** : It is the sense organ of taste. *Structures* :

Each taste bud is lined by stratified squamous epithelium and are flask-like with a wide bottom. The short and narrow neck of each taste bud is pierced by a taste pore. The taste bud possesses melon-shaped and frequent sustentacular cells and narrow, and long neuro-epithelial cells to its outer ends. The sustentacular cells are of peripheral and central types. *Distributions* : The taste buds are distributed as : (i) Mainly circumvallate and fungiform papillae contain taste buds. (ii) It will arouse a primary taste sensations. (iii) It serves as simultaneous contrast. When we apply salt on one border of the tongue, other border of the tongue becomes hypersensitive to sweet.

(k) **Olfactory bulb** : It is one of the component part of the sensory path of smell. *Structures* : The olfactory bulb comprises of a large number of nerve cells known as granules, mitral cells and tufted cells with their dendrites and axons forming the olfactory glomeruli. The cytoplasm of the granule cells possesses intranuclear rodlet, mitochondria and endoplasmic reticulum. *Function* : It forms the olfactory tract that carries the sensation of smell.

(l) **Aphasia** : It is a condition of the defect of speech occurs due to the lesions of the sensory, psychic or motor areas. *Classification* : Aphasia has been classified into : (i) Word-blindness or Visual aphasia. (ii) Word-deafness or Auditory aphasia. (iii) Pure motor aphasia or Verbal aphasia. (iv) Agraphica. (v) Cortical aphasia. *Cause* : It is caused due to the discorders of higher nervous mechanism underlying the understanding of various sensory impulses like auditory, visual, kinaesthetic, etc, the use of symbols like words, figures etc and the organisation of adequate motor impulses.

CHAPTER FIVE

SKIN AND BODY TEMPERATURE REGULATION

Introduction : The skin is the external limiting membrane between the body and the enviornment. The body in all animals has some covering to conserve the protoplasm within, to give physical protection and to exclude diseased organisms. The skin is broadly composed of outer *epidermis,* middle *dermis* and the innermost *hypodermis*. There are a number of appendages present in the skin which are nails, hairs, sebaceous glands, sweat glands and cutaneous receptors, etc. The epidermis and the nails, hairs and cutaneous glands are all ectodermal in origin but the dermis and hypodermis are mesodermal in origin. Skin serves protection of the body from pathogenic organisms, general sensations, melanin formation, body temperature regulation, respiratory function, secretion, storage, excretion, water balance, etc.

The body temperature is the residual heat remaining within the body, which is the sumtotal difference between the amount of heat produced and the amount of heat loss. Animals are generally classified as cold-blooded or *poikilothermic* and warm-blooded or *homoiothermic* in accordance with their capacity to maintain body temperature relatively constant, independently of their enviorment. The evolution from poikilothermic to homoiothermic, there exist an another group known as *hibernants* which are going into hibernation in winter, otherwise behaving like the warm-blooded animals in the remaining period. The homoiothermic animals can regulate the normal body temperature and possess an almost invariable constant temperature, viz, Birds and Mammals. The poikilothermic animals cannot regulate their own body temperature and their temperature varies with that of the surrounding medium. This class includes Reptiles, Amphibians, Fishes, Embryonic birds and Mammals and probably all Invertebrases. The hibernating animals do not require an external source of heat to raise their body temperature to normal and can rouse themselves probably by activating their large stores of body fat. Some of the cold blooded animals can hibernate in the underground hole specially in winter season.

Q. 1. Describe the Structure and Functions of Skin. What is Triple Response ?

The body in all animals has some covering to conserve the protoplasm within, to give physical protection and to exclude diseased organisms. It contains the peripheral endings of many of the sensory nerves, plays an important part in the regulation of body temperature and possesses limited excretory and absorbing powers.

Structure of Skin : The skin consists principally of a layer of vascular connective tissue, named the *Corium* or *Dermis* and an external covering of epithelium known as *Epidermis*. On the surface of the dermis layer, there are sensitive and vascular papillæ and within or beneath it, there are certain organs with special functions namely, the sweat and sebaceous glands and the hair follicles. The descriptions of the different layers of skin and its appendages are as follows :

I. Epidermis : It is the outermost layer of the skin which consists of :

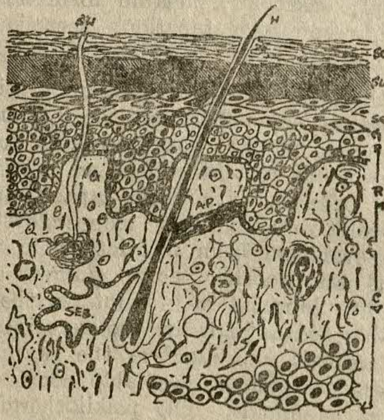


Fig. 57. Structure of the Skin.
S.C.—Stratum Corneum, S.L.—Stratum Lucidum, S. G.—Stratum Granulosum, R.M.—Rate Mucosum, C.V—Cutis vera, SW.—Sweat gland, H—Hair, A. P.—Arrectores Pilorum, B—Blood Vessel, SEB—Sebaceous Gland.

(1) *Stratum Corneum* or *The Horny Layer* : It consists of several layers of horny, squamous, epithelial cells in which no nuclei are seen. This layer is thickest on palmar regions and thinnest on outer aspect of lips. The protoplasm of this layer has been converted into *Keratin*.

(2) *Stratum Lucidum* or *The Clear Layer* : It appears as a homogeneous or dimly striated layer in section, composed of closely packed cells in which traces of flattened nuclei may be found.

(3) *Stratum Granulosum* or *The Granular Layer* : This layer consists of two or three layers of fusiform cells containing granules of eleidin which helps in the formation of keratin.

(4) *Stratum Germinativum* or *The Germinative Layer* : It consists of prikle cell layer and basal cell layer.

II. Dermis (Corium or Cutis vera or True Skin) : It is a dense white fibrous tissue consists of superficial and deeper layers and blood vessels, lymph vessels and nerves.

Appendages of Skin : There are a number of appendages present all over the skin which are as follows :

(a) **Nails** : The nails are flattened, elastic structures of a horny texture placed upon the distal parts of the dorsal surfaces of the fingers and toes. Each nail possesses body, root, nail-wall and nail bed.

(b) **Hairs** : The hairs are found on nearly every part of the surface of the body. They are absent from the palms of the hands, the soles of the feet, the dorsal surface of the dorsal phalanges, the glans penis, the inner surfaces of the prepuce and the labia. Each hair consists of root and shaft of the hair. The root of the hair possesses bulb and follicle of the hair.

(c) **Sebaceous Glands** : These are small, sacculated glandular organs, lodged in the substance of the corium. They are found in most part of skin, especially numerous in the scalp and face and the apertures of nose, mouth and external ear but they do not found in the palms of the hands and soles of the feet. The glands secrete a juice known as *Sebum* which is a natural oil for face and hair. It oilifies the hair and beautifies the face and body.

(d) **Sweat glands** : These glands are found in almost all the parts of the skin and they are situated under surfaces of the corium. The glands are of apocrine, eccrine and ceruminous in type.

(e) **Cutaneous Receptors** : Skin possesses a number of cutaneous end organs or receptors carrying cutaneous sensations like pain, touch, temperature (hot and cold) and pressure.

Functions of Skin : The skin possesses a number of appendages like nails, hairs, sweat glands, sebaceous glands, cutaneous receptors etc. and thereby it serves a good number of functions which are as follows :

(1) **Integumentary** (Protection) : Skin forms a thick layer of epithelial cells on the epidermis which makes a covering over the body.

(2) **General Sensation** (Sensory Function) : Skin performs the receptor mechanism of cold, touch, heat, pressure, pleasant and unpleasant senses which reaches in the central nervous system.

(3) **Melanin Formation** (Pigmentation) : It forms the actual colouring matter which is orginated from the melanoblast cells of the Stratum Malpighial layer of the epidermis of the skin. The colour of the body depends upon the deposition of melanin in the melanoblast cell of the stratum germinal layer.

(4) **Vitamin D_2** or **Calciferol Formation** (Synthetic Function) : Skin helps in the manufacture of ergosterol by the ultra-violet rays of the solar energy which produces bone formation in the human being specially in childhood.

(5) **Psychic Function** : Skin helps in psychical function of man. The face is the index or mirror of all emotion done by man, and all psychic functions are reflected on the face.

(6) **Storage Function** : (Reservation) : Skin functions as an important store house of blood, fat, water, chlorides and sugar.

(7) **Secretion** : The secretions of skin are of two types : (*a*) *Sebum* : It is a natural oil of skin produced by the sebaceous glands. It colourises the hair and oilifies the face. (*b*) *Sweat* : It is produced by the sweat glands present in the skin. It is an important fúnctionary product of skin.

(8) **Respiratory Function** (Gaseous exchange mechanism) : A small amount of respiratory interchange of gases occurs through the skin, but in thick-skinned animals, this is very small.

(9) **Autogenous Disinfection** : There are pathogenic organisms present in the skin and skin always tries to get rid of it. There are four methods of autogenous disinfections such as desiccation or drying, acidity of the skin, falling of epithelium and reticulo-endothelial system.

(10) **Excretory Function** : The sweat, a secretion of eccrine gland, comes out from the skin as watery fluid. Normally through the skin, chlorides, urea, uric acids, ammonia, sulphate, phosphate, lactic acid, creatinine and certain enzymes are excreted. In diabetes mellitus, sugar comes out through the in.

(11) **Body Temperature Regulation** : The skin regulates e rise and fall of body temperature through the process of onduction, convection, and radiation.

(12) **Acid-base Equilibrium** : Sweat is acidic in reaction. Acid is excreted in larger in amount along with sweat. The rise and fall of acid formation maintains the acid base equilibrium.

(13) **Water Balance** : The formation and evaporation of sweat is an important factor in the regulation of water balance of the body.

Triple Response : The persons possessing hypersensitive skin produces triple response when a moderate stroke elicits over that skin. The responses are : (1) **Red Line** : A red line appears on the line of stroke caused by vasodilation after a short interval of time. (2) **Flare** : It is a red flush appears after 15 to 30 seconds and spreads beyond the area. It is produced by arteriolar dilatation through anti-dromic axon reflex. (3) **Wheal** : It is a local oedema develops in the area of stroke and spreads a little. It is caused by escape of fluid from blood vessels resulting from increased permeability of the vessels.

Q. 2. What is Normal Body Temperature of a man ? How it is regulated ?

It is the residual heat remaining within the body, which is the sum-total difference between the amount of heat produced and the amount of heat loss. The normal body temperature varies in different types of animals. The normal body temperature of man is 98·5°F.

Normal Body Temperature Balance :

I. **Basal Heat Production** : There is a fundamental difference between cold and warm blooded animals in their relations to external temperature. The production of heat may take place in the following ways :

(*a*) *Specific Dynamic Action of food* : By the oxidation of food matters, heat is produced in the body.

(*b*) *By Entrance of Hot food* in the body and thereby production of heat in the body.

(*c*) *Entry of some amount of heat* from the enviornmental conditions like conduction, convection and radiation.

(*d*) *Exercise and Shivering.*

(*e*) *Moderate Activity* : (1) 'Unconscious tensing of the muscles. (2) Basal metabolic rate. (3) Disease.

II. **Basal Heat Loss** : The mechanism of loss of heat are as follows :

(*a*) **By the Respiratory Tract** : During respiration, a considerable amount of heat is lost from the body. In case of dog and sheep, there is an increased secretion of saliva which keeps the mouth and tongue moist and as well as the tongue is coming out.

(*b*) **By the Skin** : The skin may regulate its heat loss by changing the amount of blood passing through its sub-cutaneous vessels.

(*c*) **By Conduction** : Conduction is the transmission of heat energy from one particle of matter to the next through molecular vibration.

(*d*) **By Radiation** : Radiation signfies the transfer of infrared waves through the ether without involving a material substance. It is therefore not dependent on air movement of humidity.

(*e*) **By Vaporisation** : It depends upon the effective evaporation surface, the amount of moisture on it and difference between the vapour pressure of the ambient air and of the small of air immediately incontact with the skin.

(*f*) **By Convection** : Convection is the transfer of energy be moving molecules of air which collide with the surface, absorb heat, and then move away.

(*g*) **Effects of Clothing** : Ordinary clothes do not modify the fundamental modes of heat loss under ordinary conditions. In the clothed individual, convection and radiation account for about 55% of heat loss.

Regulation of Body Temperature : The normal body temperature is regulated by nerves, hormones and by physical mechanisms.

I. **Nervous Control** : The central nervous system is the most important regulator of the balance between heat production and heat loss. (1) Removal of the cerebral cortex in the dog, normal temperature regulation is preserved but is limited in range. (2) A decerebrate animal which has lost both cortex and thalamus cannot maintain its temperature. (3) Destructive lesions of the posterior-area of hypothalamus leadto vasodilatation and lowering of temperature without shivering.

II. **Hormonal Control** : There are a number of endocrine glands take part in the regulation of normal body temperature which are as follows :

(a) **Thyroid Gland** : The external cold via pituitary thyrotropin stimulates thyroid secretion which increases heat production, mobilised liver glycogen and stimulates neoglucogenesis.

(b) **Adrenal Cortex** : The gluco-corticoid of adrenal cortex stimulates the heat production by stimulating carbohydrate metabolism.

(c) **Adrenal Medulla** : The exposure to external cold reflexly stimulates secretion of adrenaline which stimulates metabolism and decreases heat loss.

(d) **Anterior Pituitary** : It stimulates heat production by stimulating the general metabolism by metabolic hormone.

(e) **Posterior Pituitary** : It reduces the heat loss by secreting vasopressin which constrict the vessels of skin.

(f) **Islets of Langerhans** : The insulin stimulates the heat production by oxidation of sugar.

III. **Physical Control** : The body temperature is maintained normally by a nice balance between factors concerned with heat production and heat dissipation.

(a) **In Cold Climate** : Due to low atmospheric temperature, the rate of heat loss from the body increases. The body temperature is maintained in two ways : Firstly, by increasing heat production and secondly by reducing heat loss.

(1) *Heat Production is raised by* : (i) Stimulating Thyroid and Aderenal gland and increase thyroxine and adrenaline secretion. (ii) Increasing appetite and consequently the intake of food. (iii) Due to increase production of heat by excessive exercise.

(2) *Heat Loss is reduced by* : (i) Reflex vaso-constriction of the skin, so that more heat is lost by radiation. (ii) Depressed formation of sweating cause heat loss due to less evaporation. (iii) Clothing. (iv) By increased perspiaration whereby more heat is lost by evaporation. (v) By increasing the volume of air respired.

In these ways, the normal body temperature is maintained in winter season.

(b) **In Hot Climate** : Due to high atmospheric temperature the rate of heat loss is lowered. If the humidity be also high it will hamper rapid evaporation of sweat and reduce heat loss, all the more.

Q. 3. Describe the structure, formation, composition and functions of Sweat.

Sweat glands are found in almost all the parts of the skin and they are situated under the surfaces of the dermis possessing the functions of heat regulation, water balance, acid-base regulation, excretion etc.

Structure of Sweat Glands : The sweat glands in man are of two types mainly. According to *Kuno* in 1856, sweat glands are present in the body at about 2 to $3\frac{1}{2}$ million which secrete sweat.

(a) **Eccrine Glands** : These are small glands and distributed all throughout the body. These glands are densest on the palms and soles, next on the head and much less on the trunk and extremities. The minute structures of eccrine glands are : (1) They are composed of single, unbranched coild tubes which lies in the sub-cutaneous tissue and send their ducts up through the cutis, to open on the surface by cork-screw like channels which pierce the epidermis. (2) The secreting part of the tube consists of a basement membrane lined by a double layer of cells. (3) The duct of the gland has an epithelium, consisting of 2 or 3 layers of cells with a well marked internal cuticular lining.

(b) **Apocrine Glands** : These are larger glands found mainly in the axilla and round the anus and in the female in the labia majora and mons pubis. These glands have possessed the cork-screw in appearance. They do not take part in sweating but has a sexual significance.

(c) **Ceruminous Glands** : They are situated over the external auditory meatus and act as a modified sweat glands. They are similar to apocrine glands and secrete a waxy material.

Formation of Sweat :

I. **Factors Necessary** : (a) **Physical Factors** : (1) *Exercise* : During exercise, sweat formation is increased. (2) *Fever* : Pyrexia or raised body temperature causes secretion of sweat. (3) *Fatigue* : It causes increased secretion of sweat.

(b) **Enviornmental Factors** : The factors which are concerned with increased secretion of sweat are : (1) Rise of External temperature. (2) Hot baths. (3) Artificial heating of the body by means of electromagnetic induction.

(c) **Psychological Factors** : (1) *Emotional State* : It causes increased secretion of sweat which is known as "mental sweating." (2) *During Fear* : It increases secretion of sweat.

(d) **Sexological Factors** : (1) *Sex* : To mix up with the opposite sex, sweat secretion starts. (2) *Sexual Excitement* : It causes secretion of sweat.

II. **Process of Secretion** : The secretion of sweat is mainly done by eccrine glands.

(a) **From Eccrine glands** : These glands secrete in dilute solution containing sodium chloride, urea and lactate.

(b) **From Apocrine glands** : These glands form a secretion of variable composition and of characteristic odour.

Composition of Sweat :

(A) **Physical Characteristics** :

(1) **Nature** : It is a neutral or alkaline fluid.

(2) **Amount secreted per day** : The average amount becomee 700 ml and it depends upon the heat production in the body and external temperature.

(3) **PH** : The range of PH becomes 4 to 8, according to the extent to which the lactic acid is neutralised.

(4) **Odour** : It has got characteristic odour due to the presence of volatile fatty acids.

(5) **Specific gravity** : It becomes 1002 to 1003.

(B) **Chemical Composition** : The sweat contains 98·8%

water and 1·2% solids. The solids are of inorganic and organic constituents which are :

(a) **Organic** (0·4%) : (1) Urea and sometimes uric acid—a trace. (2) Creatinine—a small trace. (3) Protein—trace. (4) Fat like matter i.e. sebum.

(b) **Inorganic** (0·8%) ; (1) Sodium Chloride—a large quantity. (2) Alkaline Sulphate—a small quantity. (3) Alkaline Phosphate—a small quantity.

(c) **Epithelial Cells** of epidermis and sweat glands.

Functions of Sweat : Sweat secreted from the sweat glands, has got many fold functions :

(1) **Excretory** : Mainly water and salts are eliminated by the skin. Sometimes certain drugs are also eliminated.

(2) **Blood Volume Regulation** : By eliminating water, sweat plays some role in the regulation of blood volume.

(3) **Keeping the body cool** : The evaporation of sweat plays an important part in keeping the body cool.

(4) **Body temperature Regulation** : By the process of evaporation of sweat, it plays in important role in the regulation of normal body temperature.

(5) **Water Balance Regulation** : The evaporation of sweat plays a valuable part in the regulation of water balance.

(6) **Acid-base Regulation** : By the excretion and formation of sweat, the ionic balance of the body fluids is regulated.

Q.4. Write Short Notes On :

(1) **Heat Regulating Centre** : The heat regulating centre is situated in the hypothalamus. *Evidences* : (i) Removal of cerebrum causes very little change in temperature regulation. (ii) Section below the hypothalamus causes disturbances of body temperature regulation and the animal becomes cold blooded. (iii) Stimulation of the anterior part of hypothalamus causes vasodilatation and sweating and helps in heat loss. (iv) Lesion of the anterior part of hypothalamus leads to a loss of power to withstand high temperature. (v) Lesion of the posterior part of the hypothalamus leads to subnormal body temperature. *Functions* : The heat regulating centre controls and maintains normal temperature of the body, the defect of which couses fever.

(2) **Sweat Glands** : These are the exocrine glands, situated in almost all parts of the skin and secrets sweat when necessary. *Types* : There are three types of sweat glands known as eccrine

glands, apocrine glands and ceruminous glands. (i) *Eccrine Glands* : These are densest on the plams and soles, next on the head and much less on the trunk and extremities. They secrete dilute sweat containing sodium chloride, urea, lactates and other salts. (ii) *Apocrine glands* : These are situated in the sexual region of the body. They do not take part in sweating but has a sexual significance. (ii) *Ceruminous glands* : They are situated over the external auditory meatus and secrete a waxy material. *Functions* : (i) Normal body temperature. (ii) Water balance. (iii) Acid-base regulation. (iv) Salt balance. (v) Excretion of water and salts. (vi) Keeping the skin moist and prevention of drying.

(3) **Sebum** : It is the secretion of the sebaceous glands. *Structures* : These sebaceous glands are small, sacculated glandular organs, lodged in the substance of the dermis. These glands are pear-shaped bodies opening into the root of hair follicles. *Functions* : (i) It acts as a bacteriostatic agent and as a lubricant. (ii) It prevents the damage of the epidermis during hot season and conservation of heat during cold. (iii) It beautifies the face and oilifies the hairs of the body.

(4) **Hypothermia** : It is a condition of the lowered body temperature when the heart rate becomes much depressed. *Cause* : (i) It is caused in freezing weather or in extremely cold water under natural conditions. (ii) It may be produced artificially for some surgical operations on the heart and great vessels. **Utility** : It is necessary for the production of brain during operation of heart and great vessels.

(5) **Cutaneous Receptors** : These are the receptors of skin, carry sensory impulses of pain, touch, pressure, hot and cold etc. *Type* : (i) *Touch*—Meissner's corpuscles and Merkel's discs. (ii) *Heat*—Organ of Ruffini. (iii) *Cold*—End bulb of Krause. (iv) *Pressure*—Organ of Golgi-Mazzoni. (v) *Deep Pressure*—Pacinian Corpuscles. (vi) *Pain*—Free Nerve terminals. (vii) *Fine touch*—Free nerve terminals around hair roots. **Functions** : The cutaneous receptors though are situated upon the skin, so these receptors serve the functions of carrying sensations of pain, touch, pressure, heat, cold, etc.

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